

MISSION TO PLANET EARTH STRATEGIC ENTERPRISE PLAN 1996-2002



National Aeronautics and Space Administration

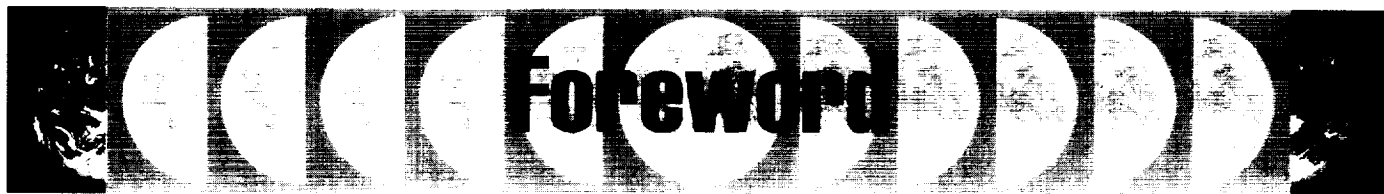


National Aeronautics
and Space Administration

Mission to Planet Earth Strategic Enterprise Plan 1996–2002



March 1996



Mission to Planet Earth's (MTPE's) first Strategic Enterprise Plan, issued in May 1995, served to define the Enterprise under the Agency's new strategic management structure. It elucidated for the first time in one document the scientific and national programmatic rationale for the whole MTPE, setting forth major goals and objectives as well as constraints. The process of producing the plan led to a new focus on customer identification and requirements which has been carried forward, with workshops and related efforts designed to structure a continuing dialog.

In the intervening months, a variety of pressures and opportunities arose which led to the initiation of a comprehensive study of how MTPE should evolve. The major changes planned as a result of these efforts are reflected in this update of the Strategic Enterprise Plan:

- ◆ A focused Science Research Plan that integrates space-based and *in situ* observational capabilities to address critical science uncertainties;
- ◆ A technology infusion plan to reduce the cost of future missions;
- ◆ A series of flight opportunities to infuse new science into the overall program; and
- ◆ A tighter coupling between NASA and NOAA to reduce costs and to improve the overall program.

This work has been reviewed in detail, and continues to be, by the National Academy of Sciences and NASA's Earth System Science and Applications Advisory Committee. Three important new initiatives are also under development and are described briefly in this plan: MTPE Education Strategy, MTPE Commercial Strategy, and an emerging concept for an Integrated Global Observing Strategy. Separate documents covering each of these initiatives are listed in Appendix 2.

This first update to the MTPE Strategic Enterprise Plan captures these new developments, and takes a significant step forward in planning this complex Earth system science endeavor. I invite you to view this plan and other information on MTPE via the Internet at <http://www.hq.nasa.gov/office/mtpe/>.

NASA's research programs are diverse, covering aeronautics, astrobiology, astrophysics, space physics, comparative planetary science, computer science, Earth system science, and life and microgravity sciences. NASA has established programs and projects to pursue each of these, resulting in a set of formidable research capabilities. A rich potential for interdisciplinary research is inherent in these capabilities. Ongoing study of Sun-Earth interactions, for example, benefits both the Space Science and the MTPE Enterprises. In the coming year, NASA will focus on designing ways to reap greater gains from this interdisciplinary potential. Can the climate modeling expertise in MTPE be employed to study climate change on Mars and Venus? Can microgravity fluid physics research contribute to climate models? Can Earth sciences research contribute to the development of controlled ecological life support systems, or vice versa? Can the Magellan radar mapping mission to Venus tell us something about the utility of higher resolution Earth-orbiting radar mappers? Next year's Agency and Enterprise Strategic Plans will describe how we will multiply the benefits of the Nation's investment in NASA science programs by leveraging the many possible connections among them.

Charles F. Kennel
Associate Administrator
Office of Mission to Planet Earth

Table of Contents

Sections

Section I.	Studying the Earth System: Science Questions with Practical Applications	1
Section II.	Providing a Global Perspective: NASA's Mission to Planet Earth	3
	Mission	
	Goals	
	Customers	
	Assumptions: An Assessment of the External Environment	
	Principles: Shaping the Internal Environment	
Section III.	Designing Research Strategies	9
	Science Priorities	
	Long-Term Measurements for Global Change Research	
	Roadmap for the Next Twenty-Five Years	
Section IV.	Implementing an Evolving Program	13
	Customer Relationships and Requirements	
	Approach to Making and Using Observations	
	Goals, Objectives, and Strategies	
Section V.	Doing Business in New Ways	27
	Program Management	
	Science Implementation	
	Commercial Strategy	
	NASA/NOAA Alignment	
	Integrated Global Observing Strategy	
	Linkages to Other Enterprises	
Section VI.	Pressing Toward the Mark: Linking Actions to Desired Outcomes	31

Appendices

Appendix 1	Acronyms	37
Appendix 2	References	39
Appendix 3	Mission to Planet Earth Launch Schedule (Through 2002)	40



Section I

Studying the Earth System: Science Questions with Practical Applications

Awarming of ocean waters in the equatorial Pacific drives increasing moisture in the atmosphere. Prevailing winds drive this moist air to the west coast of the Americas, where heavy rains cause mud slides in California and loss of life and livelihood in Peru. Meanwhile, drought conditions prevail in Australia, Indonesia, the Philippines, and southern Africa. Variability of rainfall controls the productivity of land. Volcanoes, burning of forests, and industrial activities change the composition of the atmosphere. Atmospheric changes alter the Earth's radiative balance, changing average temperature and ultraviolet radiation at the surface. Oceans affecting atmosphere, atmosphere affecting land and sea ice, land cover change affecting atmosphere and ecosystems—global changes are a complex weave of causes and effects.

Over the past 15 years, scientists have begun to see the Earth as an intricately coupled system where the interactions of land, oceans, atmosphere, ice, and biota are critical to understanding climate change on a regional-to-

global scale. Thus a new, interdisciplinary field of Earth System Science has been created. Charged with charting a course of research almost 10 years ago, the Earth System Sciences Committee of the NASA Advisory Council provided two key guideposts:

The Goal of Earth System Science: To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.

The Challenge to Earth System Science: To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity.

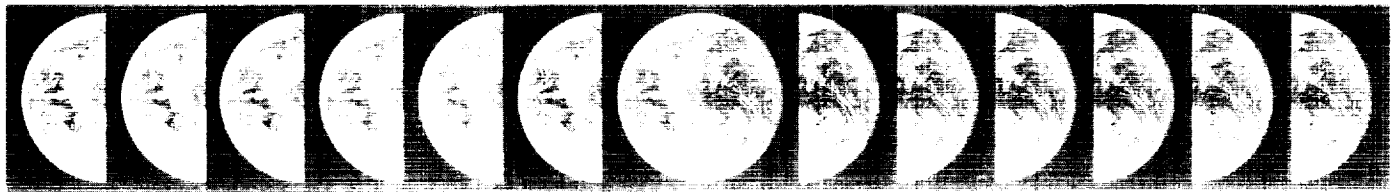
This new field is maturing rapidly, driven by the basic nature of the questions and the importance of their implications for economic growth and the environment.

Some Science Questions:

- Can climate variation be predicted a season or year in advance?
- Can long-term climate variation be detected and drivers identified?
- What are the impacts of climate change on marine ecosystems?
- How do terrestrial ecosystems respond to land cover change?
- How do sudden solid Earth changes affect the land surface?

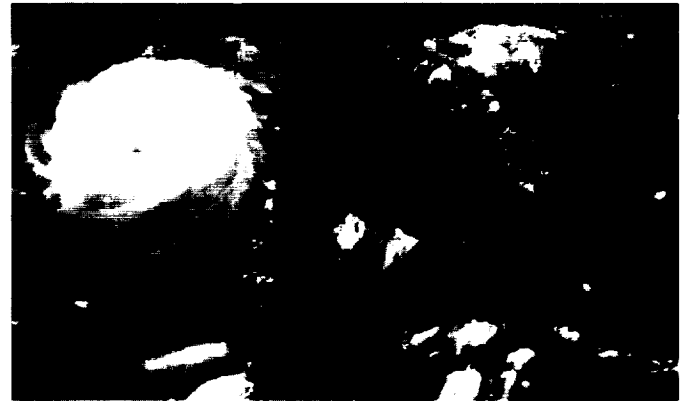
Some Practical Implications:

- Agricultural activity and drought or flood preparation could be adjusted.
- Investments in chemical and aerospace technologies might be guided.
- Productivity of fisheries could be better restored or maintained.
- Forestry and watershed management practices would be improved.
- Earthquake and flood development and aftermath could be better understood and mitigation strategies devised.



A sound scientific understanding of the Earth system provides a foundation for sustainable development—economic development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Remote sensing of the Earth, coupled with *in situ* observation and modeling activities, provides the data needed on global, regional, and sometimes local scales required to fuel that understanding. The myriad practical applications of this understanding are leading to fruitful, synergistic partnerships among public and private sector entities.

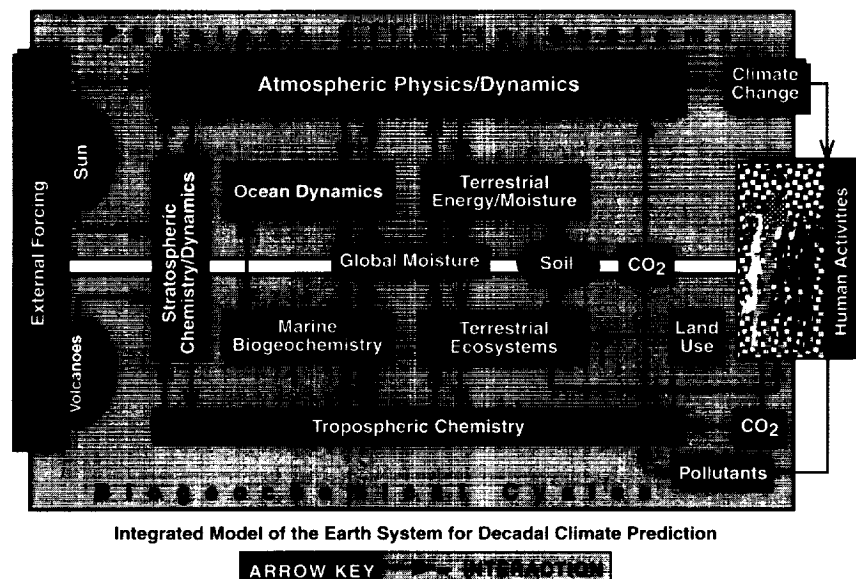
Acquiring scientific understanding will also enable intelligent decisions on environmental policy. For years, debate was hampered by scientists' inability to detect a global change signature that distinguished human-induced changes from natural variation. However, recent



Mission to Planet Earth will help scientists better predict weather patterns leading to draught, floods, or killer storms, such as Hurricane Andrew, which slammed into Florida, Louisiana, and Mississippi in August 1992.

work has led an international scientific forum, the Intergovernmental Panel on Climate Change, to conclude in their December 1995 report that "...the balance of evidence suggests that there is a discernible human influence on global climate." MTPE provides the scientific means to identify the causes and articulate the consequences of such changes, giving decision-makers an objective starting point for deliberation.

Global Climate Modeling



Schematic diagram of the Earth system and its interactions, encompassing both natural and human activities. Projecting the future climate requires understanding and quantitatively predicting how the components and interactions will change as a result of natural and human activities. [Source: Earth System Science Overview, NASA 1986]

Section II

Providing a Global Perspective: NASA's Mission to Planet Earth

The pursuit of Earth System Science would be impractical without the continuous global coverage provided by satellite-borne instruments. NASA's unique ability to develop advanced, space-based research platforms, converging with the national interest in the basic sciences and their practical benefits, has led to the establishment of one of NASA's five strategic enterprises: the Mission to Planet Earth.

Mission to Planet Earth comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis programs to convert data into new knowledge of the Earth system. Numerous users in academia, industry, and Federal, State, and Local government tap this knowledge to produce products and services essential to achieving sustainable development. Mission to Planet Earth is NASA's contribution to the U.S. Global Change Research Program, an interagency effort to

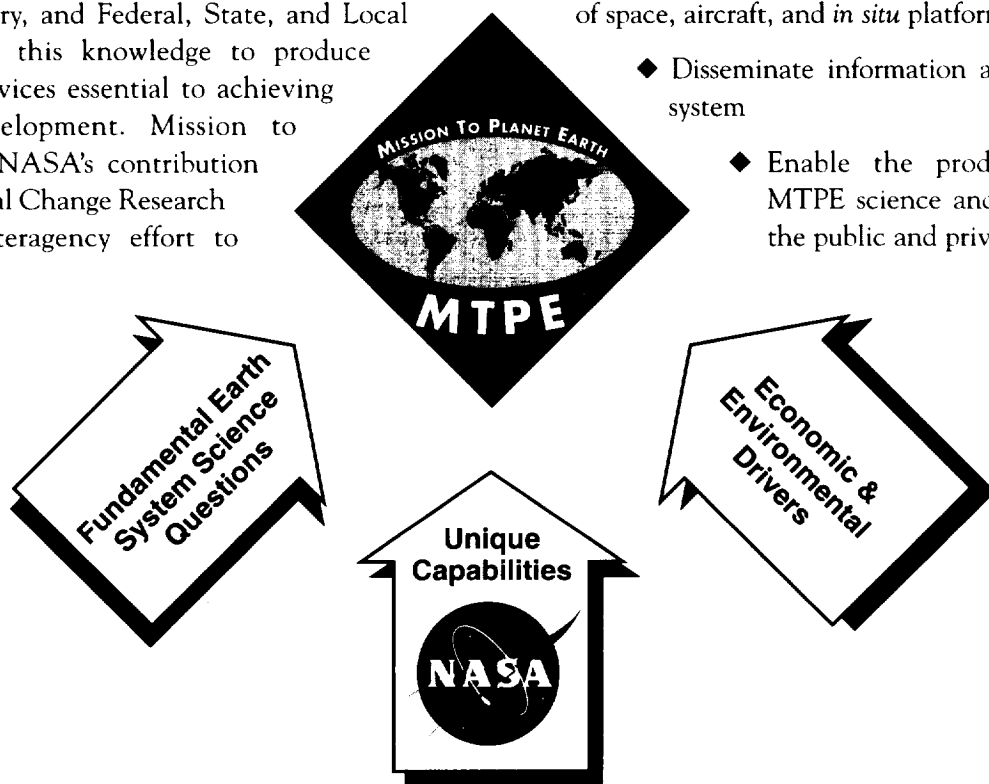
understand the processes and patterns of global change. The Earth Observing System (EOS), the centerpiece of Mission to Planet Earth, is a program of multiple spacecraft and interdisciplinary investigations to provide a 15-year data set of key parameters needed to understand global climate change.

Mission

To develop understanding of the total Earth system and the effects of natural and human-induced changes on the global environment.

Goals

- ◆ Expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and *in situ* platforms
- ◆ Disseminate information about the Earth system
- ◆ Enable the productive use of MTPE science and technology in the public and private sectors





Customers

MTPE has a broad spectrum of customers, beginning with the Earth System Science community and extending through multiple public and private sector organizations to the general public. Customers are defined in more detail in Section IV.

Assumptions:

An Assessment of the External Environment

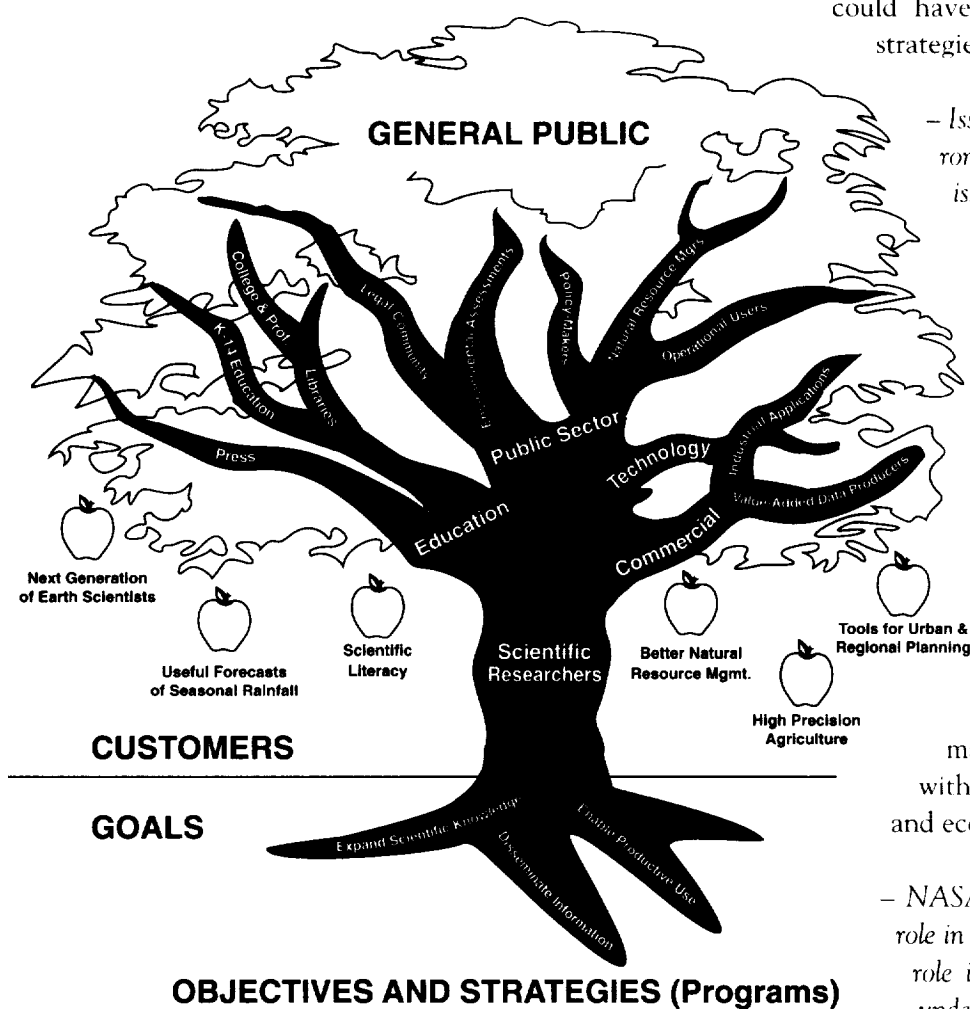
A number of key assumptions underlie this MTPE Strategic Enterprise Plan. These assumptions should remain valid for the 5-year planning horizon for this document. Changes in these fundamental assumptions could have significant effect on the objectives and strategies that follow.

– Issues involving global change and the Earth's environment will remain important global and national issues into the foreseeable future.

Although the context and the particular topics of concern will evolve, the basic questions about how the Earth system is changing and what part human activities play in that change will remain high on the list of national and international concerns. Nationally, the concern for preservation of the public health and safety and of the enhancement of our economic competitiveness will continue to be dominant issues. At the same time, there will continue to be a need for close interaction with international environmental managers, so that decisions can be considered with full awareness of all pertinent scientific data and economic impacts.

– NASA will continue to have an important statutory role in Earth scientific research and to play a significant role in the policy framework for national efforts to understand global change.

The Federal Government will continue to support research needed to address many environmental issues. NASA uses the unique vantage point of space to provide the scientific basis for informed policy-making,





and the research to support the operational missions, of other U.S. Government organizations.

– The MTPE Enterprise will have to operate within a level or declining NASA budget.

Competition for national and international financial resources will increasingly compel NASA and MTPE to find new ways to achieve goals more efficiently. It follows that even in a constrained budget, the MTPE Enterprise must make resources available to support the development and infusion of new technologies to enable an improved rate of science return on the national investment.

– Clear links exist between the MTPE program and areas of high public concern. It will be essential to maintain clear communications with the public on these issues to enable informed decisions on the program.

It is critical that MTPE foster a shared vision of science priorities within the scientific community and highlight areas of mutual interest with the industrial community. MTPE scientists and engineers are active participants in this process and lead the way through state-of-the-art research and participation in scientific and technical forums; they must also be encouraged to share their knowledge in forums with broader public access. MTPE will continue the practice of conducting workshops and other forums to seek out the needs of the public and commercial communities for Earth System Science data and technology, and work with these communities to meet their needs.

– MTPE will be implemented within an international framework.

The United States is providing roughly 50 percent of the world investment in space-based remote sensing of the

Earth for environmental research through 2000. MTPE incorporates extensive international collaboration in both mission development and scientific research, with agreements in place covering \$3.5 billion in foreign investments. As the new century unfolds, MTPE intends to shape and be shaped by the development of an international, integrated global observing strategy.

– MTPE-generated data and technology have clear, recognized value beyond science, for example, in the commercial, educational, and monitoring areas.

MTPE recognizes these leverage points and will amplify them in order to achieve stronger returns to the American taxpayers for their investment in space. At the same time, these leverage areas provide opportunities for closer international and interagency collaboration (as with NOAA), greater involvement of the private sector in collaborative relationships with MTPE, and long-term ties to the national educational community. Section VI provides a view of the value of MTPE products in these broad communities.

Principles: Shaping the Internal Environment

Seven basic principles have been crucial in guiding the process that developed our strategy for implementing the MTPE mission.

External Program Review: Most of MTPE's customers and much of the required expertise are outside NASA. Program priorities must reflect consensus with the larger scientific and policy communities. A wide range of reviews is conducted by the National Academy of Sciences, through among others, the Space Studies Board. We work closely with the Academy's Board on Sustainable Development, which governs its environment and natural resources work. We have established an



Earth Systems Science and Applications Advisory Committee to work closely with MTPE managers to ensure that our program planning and direction are consistent with our mission and national priorities.

Peer Review as the Foundation for Project Selection:

Project selection based upon competitive, peer reviewed proposals, is the foundation upon which the MTPE science program is built. Peer review is recognized among science policy makers and practitioners as fundamental to ensuring a world-class program. It aids science program managers in their exercise of scientific leadership in establishing program direction and making decisions on new avenues of research. Scientific and technical peer review provides the best critical evaluation of ideas and fosters the best use of limited research resources. The same peer review process is applied to all MTPE research efforts, whether they come from within NASA or from the external community.

World-Class Science and Technology Content: Striving for program excellence, addressing the most important scientific problems, and doing it objectively and well are the guiding foci of MTPE. To do this, MTPE continues to strive for mission success and supports NASA's safety, reliability, and quality processes. MTPE also seeks to maintain and strengthen the in-house science staff to ensure the scientific quality of observation programs and lead the scientific community in analysis of the resulting data.

A Balanced Program: Using NASA's special capabilities, MTPE seeks to maintain a balanced program across the Earth science disciplines and among the various MTPE program elements. In most cases, this does not imply equivalent resource allocations, and the balance points move with changes in budget constraints and advances in science and technology. We strive to achieve balance in the following key areas:

- 1) Investment in research and analysis compared to total program investment;
- 2) *In situ* observations and space-based observations;
- 3) Nonclimate research with climate research, consistent with Earth system science goals;
- 4) Commitment to key data products with hardware development constraints in the planning process;
- 5) Long-term science questions with short-term policy demands;
- 6) Long-term data continuity with technology development and evolving science priorities; and
- 7) Process studies, process modeling, and global modeling.

Diversity: MTPE supports the development of a diverse workforce and Earth science community. Diversity is a fundamental ethical dimension of global stewardship. Diversity brings the strength of multiple viewpoints. A work style of innovation within MTPE must include the proper development of personnel resources for the workforce. The MTPE Enterprise must reflect the face of America.

National and International Policy Relevance: MTPE originated from a national need for a more reliable and predictable understanding of the changes occurring in our global environment; as a result, MTPE must be acutely attuned to the need for providing products that serve the national and international policy-making community. Strong links between MTPE and the national and international policy-making community are critical to maintaining program relevance.

Partnership with Other Domestic and International Organizations: Global environmental concerns require a global response. MTPE is an integral part of a cooperative interagency and international research endeavor, with all parties making essential contributions. Interagency activities are coordinated through the U.S.



Global Change Research Program, the Task Force on Observations and Data Management, the Subcommittee on Natural Disaster Reduction Research, and the other subcommittees under the Committee on Environment and Natural Resources. International activities include the World Meteorological Organization's World Climate Research Program and the United Nations International Geosphere/Biosphere Program. The

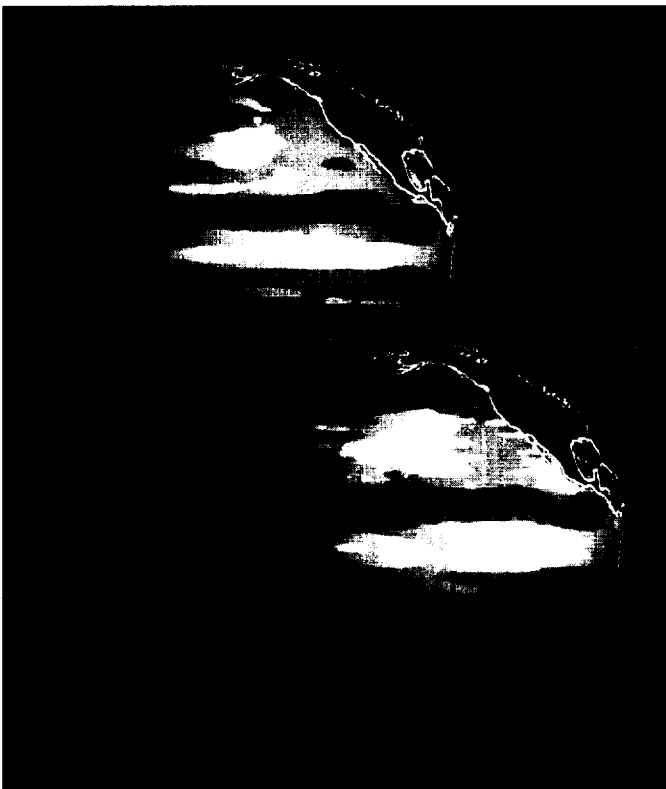
global nature of the issues involved, the critical need for credibility in data, and the increasingly constrained resource environment mandate that MTPE foster partnerships and alliances across organizational and national boundaries. International partnerships also foster consensus on the results and implications of the research, facilitating international action.



Designing Research Strategies

Science Priorities

The scientific issues of concern to MTPE are among the most complex and most relevant of any major scientific research program. The basic scientific goal of MTPE is to understand the Earth as an integrated system, including the effects and couplings of the solid earth, land surface, oceans, atmosphere, and biota. This may be the



TOPEX/Poseidon spacecraft observations (bottom) of sea level in the Pacific Ocean in December 1994—when the 1994-95 El Niño event reached its peak—are compared to computer simulation (top) of a two-year mean for the same region. The range of sea level shown is about 30 centimeters. Effects of this El Niño event on the atmospheric jet stream were partly responsible for the heavy rain in California in the winter of 1995.

largest interdisciplinary effort ever undertaken. Results of MTPE science provide an objective starting point for the development of sound global environmental policy. MTPE science can also make important contributions to the reduction of hazards to human life and property from natural events such as earthquakes, volcanic eruptions, severe storms, and floods. MTPE science also gives rise to a host of practical applications designed in part or in whole by commercial firms and State and local governments.

Balancing the state of Earth System Science with NASA capabilities, funding constraints, the research priorities of the U.S. Global Change Research Program, and the needs of external communities, MTPE has established the following science priorities for the period 1996–2002. These provide unifying themes for MTPE science and missions. All five areas of research will be pursued regardless of total funding level.

- ◆ **Land-Cover Change and Global Productivity—**
Document and understand the trends and patterns of change in regional land-cover, biodiversity, and global primary production
- ◆ **Seasonal-to-Interannual Climate Prediction—**
Provide global observations and scientific understanding to improve forecasts of the timing and geographic extent of transient climate anomalies
- ◆ **Natural Hazards—**
Apply unique MTPE remote sensing science and technologies to disaster characterization and risk reduction from earthquakes, wildfires, volcanoes, floods, and droughts



- ◆ **Long-Term Climate Variability—**
Provide global observations and scientific understanding of the mechanisms and factors which determine long-term climate variations and trends
- ◆ **Atmospheric Ozone—**
Detect changes, causes, and consequences of changes in atmospheric ozone

MTPE is committed to the advancement of Earth System Science. In this context, the five priority areas may change beyond the 5-year horizon. Research in other areas, such as physical oceanography and solid Earth dynamics, is also conducted, often jointly with other agencies, to strengthen the integrated Earth System Science endeavor.

Long-Term Measurements for Global Change Research

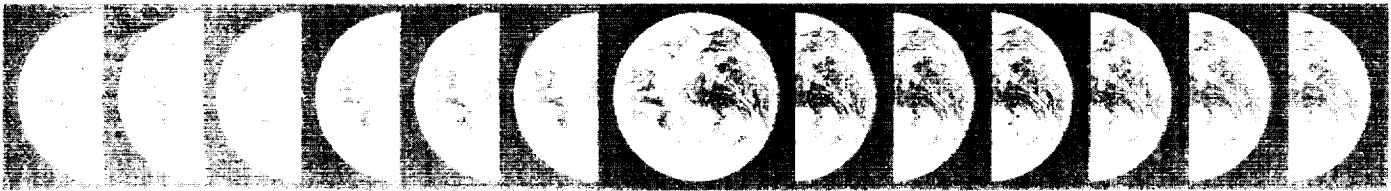
MTPE is committed to measuring a specific series of 24 prioritized global environmental variables, for a 15-year term. This measurement set has evolved through a series of national and international reviews as the principal set required to understand the complexities of global climate change. These measurements will provide the comprehensive data sets needed to drive an increasingly comprehensive suite of predictive models. In addition, they are essential to progress in the four maturing science areas identified by the National Academy of Sciences Board on Sustainable Development in its September 1995 report (see Appendix 2), and align closely with the science priority areas identified in Section III.

The current spacecraft and instrument configuration to carry out this task is near minimum cost, given the state of current technology. However, NASA is not committed to specific instrument or spacecraft designs for the

The 24 measurement areas are:

ATMOSPHERE	Cloud Properties Radiative Energy Fluxes Precipitation Tropospheric Chemistry Stratospheric Chemistry Aerosol Properties Atmospheric Temperature Atmospheric Humidity Lightning
LAND	Land Cover & Land Use Change Vegetation Dynamics Surface Temperature Fire Occurrence Volcanic Effects Surface Wetness
OCEAN	Surface Temperature Phytoplankton & Dissolved Organic Matter Surface Wind Fields Ocean Surface Topography
CRYOSPHERE	Ice Sheet Topography & Ice Volume Change Sea Ice Snow Cover
SOLAR RADIATION	Total Solar Irradiance Ultraviolet Spectral Irradiance

succeeding generations of measurement collection. Within the scope of the current program, MTPE is committed to identifying sufficient flexibility to permit technology investments which will result in long-term savings in later generations of the EOS program. In so doing, the measurement sets will be preserved, but the technologies and platforms used to collect and analyze those data will almost certainly change.



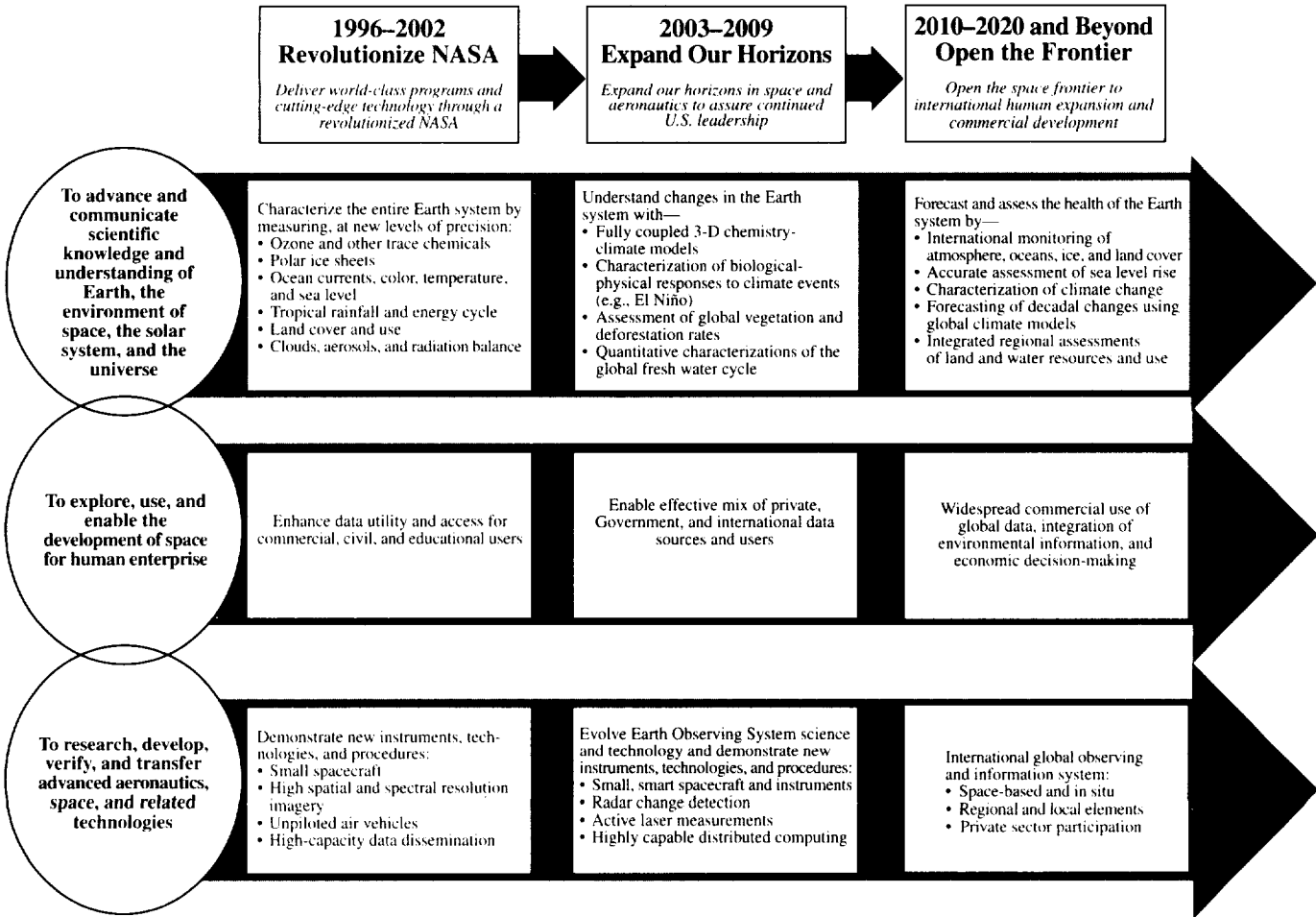
The evolving nature of Earth System Science and associated measurement technologies necessitates that, while the commitment to these measurements is being fulfilled, ways to make new measurements are found. As these new data are analyzed, some of the new measurements may be found to be of enormous importance in our understanding of global change. Therefore, in conjunction with the EOS program, smaller-scale, more flexible programs are needed to capitalize on the advancement of science and technology.

Simply making the measurements is not enough. MTPE

is also committed to conducting the accompanying research required to analyze, verify, interpret, and understand the implications of these measurements. In many cases, this means making the correlative *in situ* measurements required for a complete understanding of the subject phenomenon. It is the scientific understanding that is the goal.

Roadmap for the Next Twenty-Five Years

The evolving nature of MTPE is depicted in the following Roadmap figure, which lays out a 25-year vision for the





Enterprise. The figure is an expansion for MTPE of the Agency Roadmap in the NASA Strategic Plan. The Roadmap shows the anticipated progression of science and applications emphases, binding these streams of activity together in the context of the NASA mission statement. The three-part NASA mission statement is shown

in the ovals on the left side of the figure, with the three columns depicting three “business cycles,” each labeled with the anticipated major theme for that cycle. This edition of the MTPE Strategic Enterprise Plan focuses on implementation of the first cycle, and also describes activities which prepare for the subsequent cycles.



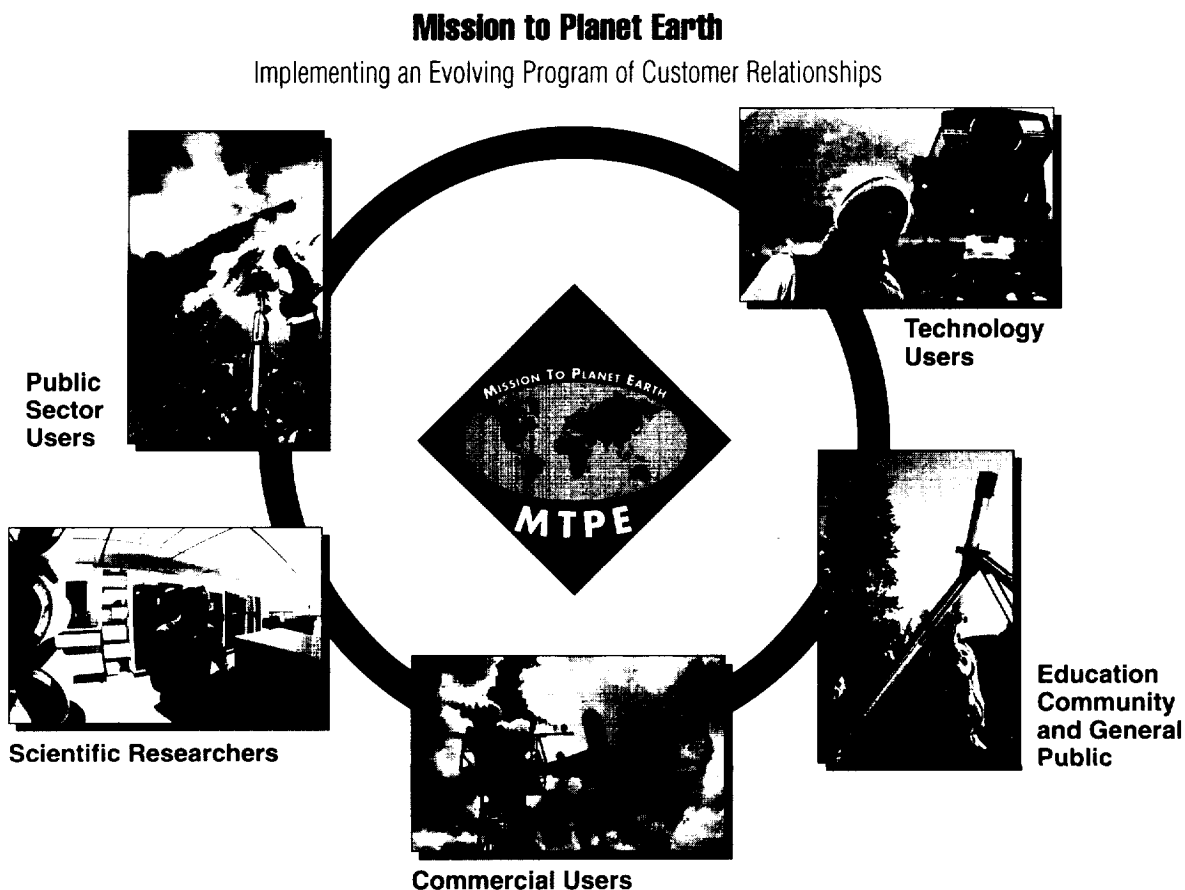
Implementing an Evolving Program

Customer Relationships and Requirements

MTPE's highly diverse customer base includes science discipline researchers, policy makers at the Federal, State, and local levels, international scientific and policy entities, educators, private sector firms, and individual citizens. MTPE has customers not only nationwide, but worldwide, with data both produced and used by space agencies and researchers from many nations. Ultimately, our customer base also includes our children and grandchildren, who will benefit from the enhanced understanding of the global climate system which MTPE is designed

and committed to provide. While most of these customers seek data or data products via the Earth Observing System Data and Information System (EOSDIS), others seek technologies developed in MTPE flight programs.

Our customer base can be usefully categorized into five types. The MTPE goals, objectives, and strategies are focused on identifying and meeting our customers' requirements. Listed for each are examples of our customers' desired outcomes and product types they generate with MTPE data and/or assistance.





- ◆ **Scientific Researchers** Scientific researchers constitute the largest class of users of MTPE data sets, and drive the requirements for EOSDIS. Some of these scientists develop and operate instruments or conduct field campaigns to generate data and data products. Others access these data, including those archived in the EOSDIS, for use in analyses, modeling, or assessments. Laboratory investigators use these data to conduct process-oriented research. Scientists' products are inputs for other classes of customers.

Desired Outcome: New knowledge of the Earth system

- Data on natural and anthropogenic phenomena
- Predictive models' coupling elements of the Earth system

- ◆ **Commercial Users** Many of these are "value-added" service companies, which pull data sets from EOSDIS, process them to a higher level, and market images or other data products to a wide variety of customers. Others find remote sensing data to be useful in some aspect of their business to monitor the health of their assets or production processes (e.g., forests, utility right-of-ways, and ocean fishing locations). Commercial users can use EOSDIS products as market and product research tools to aid in the development of their own operational systems and data products.

Desired Outcome: Tools for improved decision-making to increase return on investment; increased synergy of MTPE and commercial data

- Forecasts for agriculture
- Images revealing the health and maturity of forests and agricultural areas, or surface features for land use planning
- Images pointing to the location and health of fish stocks

- ◆ **Public Sector Users** These include natural resource managers, operational users (e.g., USDA), policy formulators and decision-makers (including regulatory agencies), public health officials, and the legal community. These users may be at the Federal, State, or local level. At the international level, they include the Framework Convention on Climate Change, for which MTPE provides assessments of the effects of international action under the Montreal Protocol on Ozone-Depleting Substances.

Desired Outcome: Tools for decision-making in areas of public management and policy responsibility

- Integration of remotely sensed data into State and local decision processes
- Land cover and land use change detection
- Assessments of environmental quality
- Evaluation of effectiveness of international agreements
- Atmospheric data, including volcanic eruption consequences for aviation safety and guidance for aerospace manufacturers
- Improved flood warning and vulnerability assessment
- Identification of rapidly deforming land surfaces in seismically active urban areas.

- ◆ **Education Community and General Public** These users can be broadly categorized into: K–14 educators and students; collegiate and professional education; and libraries, the press, and the public.

Desired Outcome: Products and services to enhance educational quality and public awareness

- Pre-service and in-service teacher training tools
- Communications products and tools, including news releases/briefings, video footage, and Internet materials, to enhance public understanding of MTPE via both direct access and media coverage



- Curriculum enhancements with better data access and data visualization techniques

◆ **Technology Users** These public and private sector entities use technologies developed by MTPE for their own activities.

Desired Outcome: Advanced technologies to bring new or cheaper products and services to market or public use

- Advanced instruments for weather monitoring
- Techniques for monitoring facilities and resources which reduce cost
- Information and data processing technologies

MTPE identifies scientific community and public sector needs through the interaction of the U.S. Global Change Research Program, a variety of formal international committees and working groups, and the active involvement of advisory bodies, principally the National Academy of Sciences and the Earth System Science and Applications Advisory Committee. We conduct workshops with a broad range of commercial users to identify their needs and discuss ways MTPE can encourage the commercial market for remote sensing data and technology. MTPE is actively engaged in education forums at all levels to design products and services, such as materials for in-service and pre-service teacher training and Earth System Science curriculum enhancement. All these interactions will enable MTPE to plan the evolution of measurement capabilities, scientific priorities, assessments, and EOSDIS.

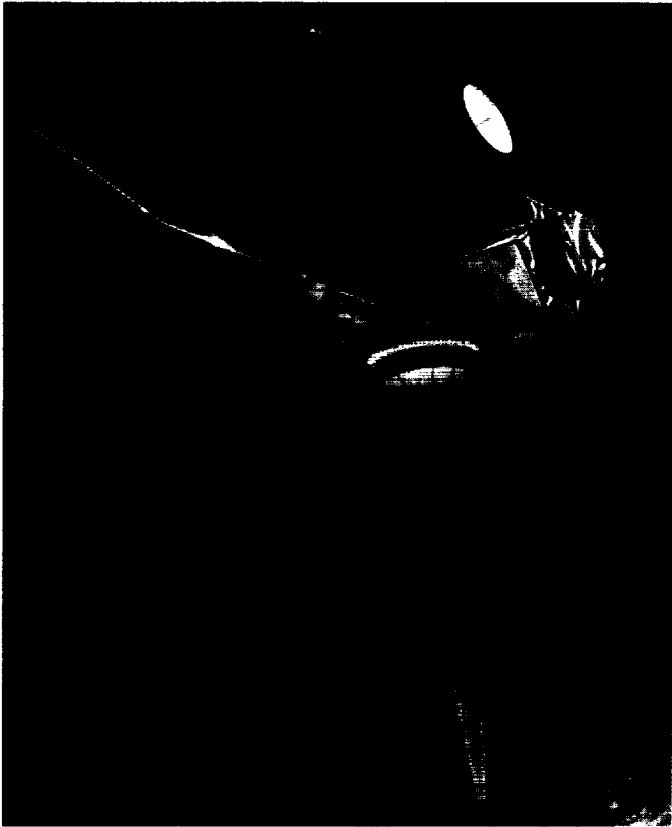
Approach to Making and Using Observations

◆ **Pre-EOS MTPE Program** Phase One of the MTPE program is designed to provide global measurements of major Earth system components to improve our knowledge of basic processes prior to the EOS era.

These include the operational Upper Atmosphere Research Satellite (UARS), which confirmed the anthropogenic origin of ozone-depleting substances, and TOPEX/Poseidon, which is detecting sea level change worldwide. Phase One continues with the NASA Scatterometer (NSCAT), which will detect ocean surface wind vectors from Japan's ADEOS satellite, and the Tropical Rainfall Measuring Mission (TRMM), also conducted jointly with Japan, which will for the first time provide an accurate assessment of rainfall and associated energy release over the oceans in these key latitudes. A proposed Shuttle Radar Topography Mission providing the first global (within 60° N&S) digital topographic characterization of the Earth may also be launched in this timeframe.

◆ **EOS Program** MTPE is taking an evolutionary approach to planning the implementation of the EOS program. Over the past few years, efforts have focused on defining a configuration for the first series of EOS spacecraft which reflected a stable balance among budget constraints, available technology, and scientific requirements. Having achieved this goal, MTPE has begun to focus on the second and third series of EOS missions. A comprehensive study of MTPE evolution was conducted in the spring and summer of 1995. The result of this review is an MTPE Enterprise that dramatically reduces EOS life-cycle cost, is more flexible in implementation, uses the latest available technology, builds on international partnerships, and is of greater utility to the science and commercial communities. MTPE will continue to refine this plan and seek the advice of the National Academy of Sciences and other external advisory bodies along the way.

We will seek to expand our partnerships with other Federal agencies, the commercial sector, and the inter-



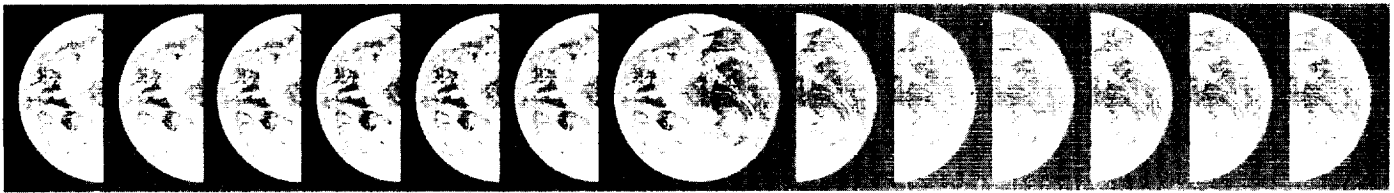
The Ocean Topography Experiment (TOPEX)/Poseidon is a cooperative project between the United States and France to develop and operate an advanced satellite system dedicated to observing the Earth's oceans. The mission provides global sea level measurements with an unprecedented accuracy.

national community. EOS is already integrated with climate-related research and capabilities conducted by 17 other Federal agencies through the U.S. Global Change Research Program (USGCRP). We are pursuing expanded integration of measurements and data management capabilities with NOAA, especially for the second and subsequent phases of EOS, when new instrument capabilities will have been demonstrated and data requirements become more operational in nature. Recognizing the immature nature of many commercial remote sensing capabilities at this time,

we are also attempting to stimulate the development of this sector, both as a provider and a user of MTPE data.

In the international arena, MTPE is already leveraging its investments through partnerships representing over \$3.5 billion in other nations' investments. Further, NASA has also negotiated for access to data from missions costing our foreign partners almost \$5 billion more. In addition to stretching the dollars invested in MTPE by American taxpayers, international collaboration builds worldwide confidence in scientific results and environmental assessments. Foreign governments are providing instruments to fly on EOS platforms, and the United States is providing instruments for other nations' platforms. The first EOS series has achieved the limits of international hardware contributions, and MTPE will explore new collaborative opportunities in the second and third. Ultimately, the outcome and payoff of this international involvement would extend to development of a framework for nations to commit to fulfilling requirements of an International Global Observing Strategy (IGOS; described in Section V).

- ◆ **Focused Technology Infusion Strategy** A major piece of this strategy is the New Millennium program (NMP), a cooperative program with other NASA enterprises and industry with a goal of one Earth science-oriented technology development mission per year beginning in 1998. MTPE will establish a process that annually considers advanced technologies and operational concepts. A Technology Infusion Management Plan will establish such procedures. The process will provide for a biannual technology readiness review and assessment that leads to specific technology development and infusion plans. Technology implementation plans will be reflected in annual program budget submissions.



◆ **Small Satellite Opportunities for Emerging Science Priorities** Opportunities to accommodate newly emerging scientific priorities and infuse new scientific participation into MTPE are required to complement the longer term commitment of EOS to global climate change. MTPE is implementing a new Earth System Science Pathfinder (ESSP) program to provide these opportunities in the form of small, rapidly developed and deployed satellites. The ESSP program's first Announcement of Opportunity (AO) will seek two missions meeting the following programmatic guidelines:

- Focused on high-priority Earth System Science
- Limited to a total mission life-cycle cost from NASA (less than \$100 million including data analysis)
- Managed by the Principal Investigator who is accountable for mission success
- Launch ready in 36 months or less following authority to proceed
- Compatible with EOSDIS standards, including immediate data release

Release of the inaugural ESSP AO is planned for mid-1996, with selections based on "best value science" criteria. AO's for additional missions will be released periodically. A number of new management practices will be employed in order to achieve the goal of yearly launches beginning in 1999.

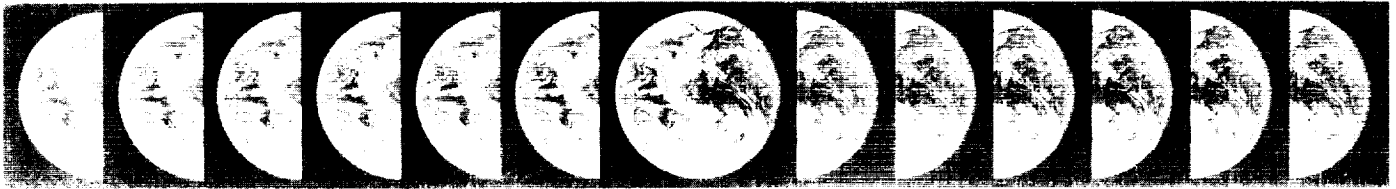
◆ **Research and Analysis Program** A strong program of peer-reviewed, grant-funded research provides the intellectual capital on which MTPE defines and implements flight programs. Research and Analysis activities may define requirements for flight programs, use data from them, or be separate streams of research which round out the research required to answer fundamental science questions. It includes

modeling activities which can lead to improved climate forecasting and other tools with high potential for societal benefit.

◆ **In Situ Observation Programs** Some observations required for Earth System Science are best made from *in situ* platforms such as aircraft, balloons and ground-based instruments. These may be correlative to space-based sensors or adequate in themselves to address phenomena on a local-to-regional scale. As a result of



NASA's ER-2 is the country's premier high-altitude civilian research aircraft. Flying in the lower stratosphere, it allows scientists to make *in situ* measurements for the study of atmospheric chemistry, such as ozone breakdown. It also serves as a testbed for instruments planned for future Earth-orbiting spacecraft.



the report of the Board on Sustainable Development, MTPE is assuming more responsibility to acquire all the data required for its selected scientific questions (sometimes from other agencies), rather than focusing on those obtainable from its traditional platforms of expertise. To this end, MTPE has recently initiated activities leading to the formation of an interagency team to assist in defining MTPE's long-term strategy for the utilization of remotely piloted vehicles (RPV's). This effort builds on the development of a prototype RPV called Theseus, under a cooperative agreement with Aurora Flight Sciences of West Virginia, West Virginia University, and Fairmont State College, which will be undergoing flight testing in the spring of 1996. RPV's promise a new, cost-effective means of *in situ* data gathering for atmospheric chemistry research.

- ◆ **Applications Program** In addition to building scientific understanding, MTPE will contribute to more direct tangible economic and societal payoffs from the public's investment in Government research. Accordingly, MTPE has expanded its customer definition beyond the science community to include public and private sector users of Earth science data for practical applications. MTPE seeks ways to build bridges between the research- and the applications-oriented communities by defining the needs of the broader user community and identifying MTPE assets and science results which can meet those needs. Pilot demonstration projects will validate the methodologies of these applications to ensure effective knowledge transfer of theory and practice to the end users.

These images show the same portion of the State of Rondonia, Brazil, in which deforestation of tropical forests has taken place between 1975 and 1992. Systematic cutting of the forest vegetation starts along roads and then fans out to create the "fishbone" pattern shown in the 1992 image. Brazilian and U.S. scientists are actively engaged in study of land cover change in the Amazon region.

Goals, Objectives, and Strategies

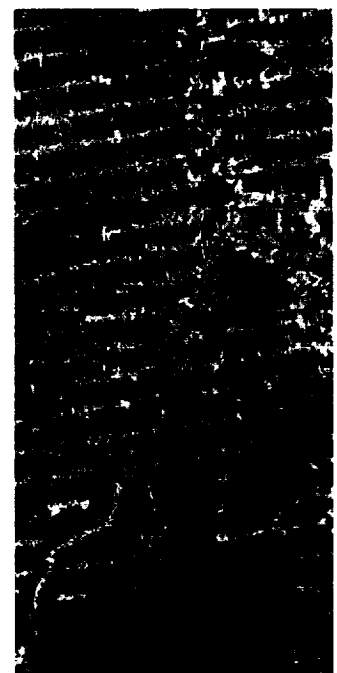
For each of the goals identified in Part II, a detailed set of objectives and strategies has been defined.

GOAL 1: Expand scientific knowledge of the Earth system using the unique vantage point of space

Objective 1.1 *Develop the capability to perform repeated global inventories of land use and land cover from space, and develop the scientific understanding and models necessary to evaluate the consequences of observed changes.*

Strategies

- Design and implement a research program with the following elements:
 - Identify and measure forcing factors
 - Climatic and ecological drivers
 - Socioeconomic drivers coupled to landscape changes



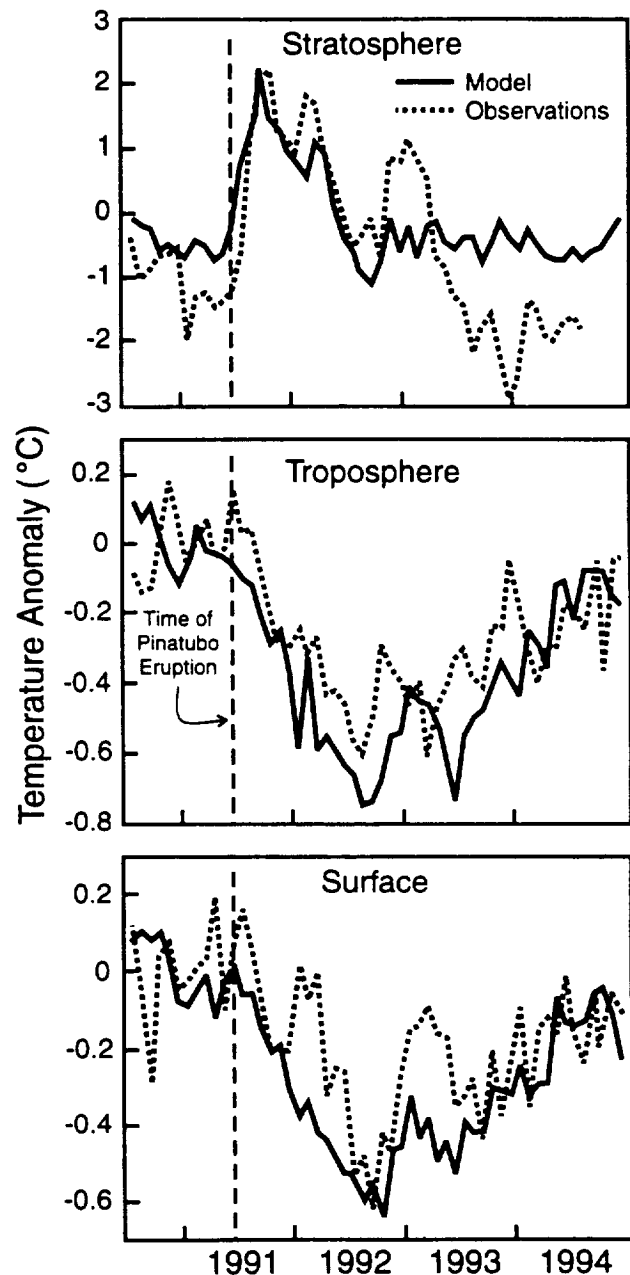


- Responses and consequences
 - Identify land cover type distribution and track conversion
 - Land use intensification in agriculture and agro-forestry and rangelands
- Modeling and implications
 - Incorporation of land cover/land use change into existing biogeochemical, biophysical models, and climate models
- Techniques and methods
 - Develop, refine, and implement techniques and methods for remotely sensing land cover, land use, and vegetation characteristics
- Release solicitations for process-based, *in situ*, and remote sensing studies of land use/land cover for key regions of change in:
 - U.S. State and local jurisdictions
 - Amazon Basin
 - Mexico
 - Southeast Asia
 - Southern Africa
 - Russia
 - China
- Conduct workshops and specialized analyses targeted to coordinate with USGCRP, the International Geosphere-Biosphere Program (IGBP), and the World Climate Research Program (WCRP).
- Begin to assimilate data from Landsat-7 and EOS-AM1 into regional process studies and models in 1998.

Objective 1.2 *Develop and use remotely sensed and in situ observations to monitor, describe, and understand seasonal-to-interannual climate variability, with the aim of improving skill in long-range weather forecasts and seasonal climate predictions.*

Strategies

- Develop new lidar and radar technologies for measurement of climatically important variables such as water vapor, cloud properties, winds, precipitation, and aerosols.
- Improve existing remotely sensed observations of surface winds, sea surface temperatures, sea ice, sea level, precipitation, and latent heat over the oceans.



Comparison of climate model predictions, made immediately after the eruption of Mt. Pinatubo in June 1991, with subsequent observations. Volcanic emissions had a marked, temporary effect on global average temperatures.

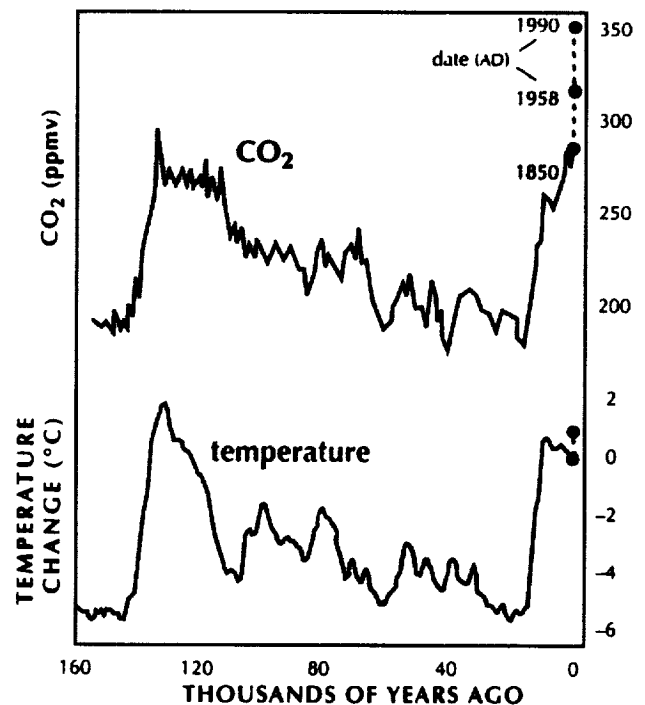


- Improve the characterization of land surface processes in the transfer of radiation, heat, and water between the biosphere and soil and the atmosphere.
- Develop and improve methods for assimilating both remotely sensed and *in situ* observed data with coupled ocean-atmosphere-land models to produce research-quality data sets.
- Improve the skill of predicting seasonal-to-interannual climate variations using coupled models of the upper ocean-atmosphere-land system.
- Observe, characterize, understand, and experimentally predict anomalous climatic events that pose significant hazards for human society.
- Coordinate closely with NOAA to accomplish objectives of USGCRP, GEWEX, CLIVAR, and GOALS.
- Complete first set of global models for coupling troposphere, stratosphere, ocean, land, cryosphere, chemistry and biosphere by 2010.
- Improved determination of climate sensitivity and analysis of the role of anthropogenic forcings in observed climate variations and trends by 2010.
- Improved assessment of global sea level change and its causes by 2005.
- Ability to make limited realistic predictions of regional climate changes and their impacts that will occur in response to long-term climate forcings by 2010.
- Ongoing major contributions to national and international scientific assessments of climate change, such as IPCC, that will provide the scientific basis for environmental policy formulation.

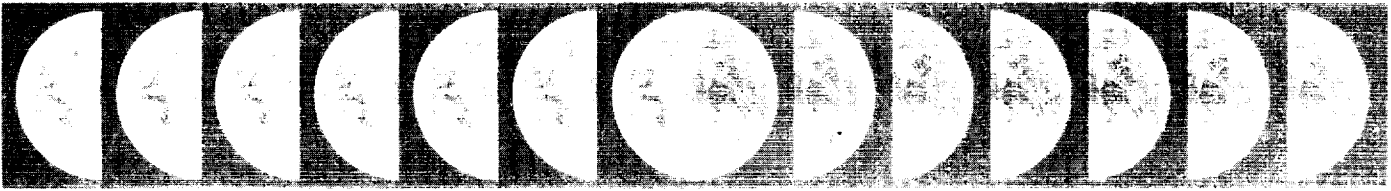
Objective 1.3 *Understand the causes and consequences of long-term (decades to centuries) climate system variability.*

Strategies

- Produce a multidecadal record of primary global climate forcings (e.g., solar irradiance, atmospheric composition) by 2000.
- Multidecadal record of primary radiative feedbacks on climate, including their variations during a series of climate events, such as El Niño and volcanic eruptions by 2000.
- Multidecadal record of key climate diagnostics by 2010: troposphere/stratosphere temperature and humidity profiles, ocean and land surface temperatures, sea ice and snow cover, radiation budget at top of the atmosphere and surface, precipitation, and ice sheet volume.
- Improved global model treatments of atmospheric radiative transfer, atmospheric chemistry, cloud physics, aerosol processes, precipitation, air-sea exchanges, sea ice, ground hydrology, and ocean circulation by 2005.



CO₂ and temperature records from Antarctic ice cores over the past 160,000 years, and recent atmospheric measurements.



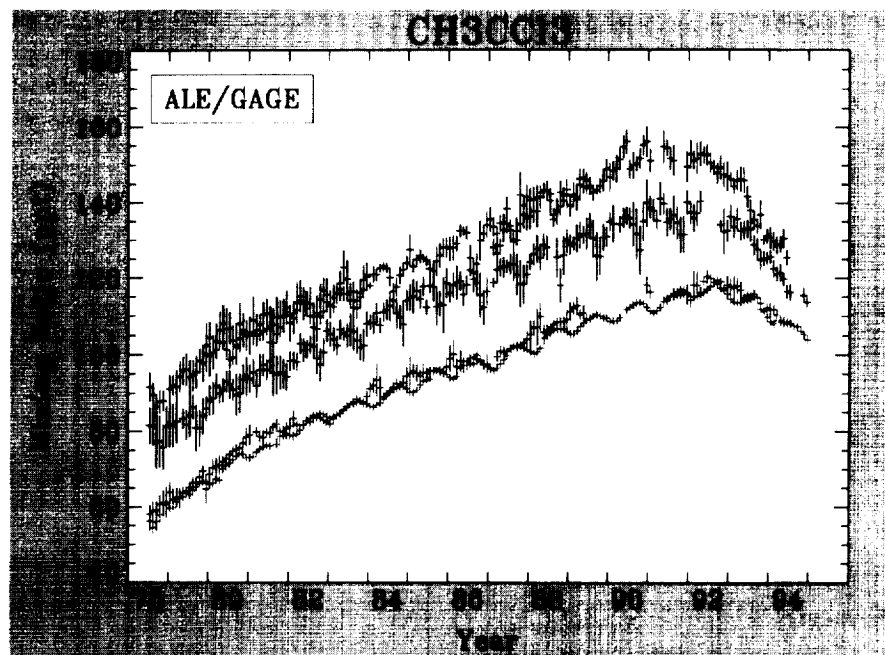
Objective 1.4 *Develop understanding of processes affecting distributions of ozone and oxidizing species in the global troposphere and stratosphere, to determine those distributions, including their spatial and temporal dependence, and to quantitatively characterize observed past and, through the use of predictive models, potential future changes in these distributions.*

Strategies

- Improve the understanding of processes affecting distributions of ozone and oxidizing species in the global troposphere and stratosphere through laboratory studies of reaction kinetics and molecular photochemistry and spectroscopic research.
- Provide cross-calibration data for U.S. and foreign instruments on aircraft and satellite platforms using NASA satellite, aircraft, balloon, and ground-based instrumentation.
- Improve understanding of the large-scale movement of air between the stratosphere and troposphere and among tropics, mid-latitudes, and polar regions through a series of airborne and balloon-borne measurements, such as the Stratospheric Tracers of Atmospheric Transport (STRAT), Observation from the Middle Stratosphere (OMS), and Tropical Ozone Transport Experiment/Vortex Ozone Transport Experiment (VOTE/TOTE) missions.
- Improve the characterization of the roles of natural and anthropogenic forcings on the ozone abundance and distribution and the attendant effects on climate and ultraviolet radiation on the Earth's surface through laboratory studies and field measurements, such as the Photo-

chemistry of Ozone Loss in the Arctic Region in Summer (POLARIS) input into the latest modeling studies.

- Improve the understanding of the anthropogenic and natural processes that control the tropospheric ozone levels over the eastern tropical Pacific and the North Atlantic through an aircraft-based campaign called the Pacific Exploratory Mission-Tropics (PEM-Tropics) in 1996 and Subsonic Ozone and Nitrogen Experiment (SONEX). Conduct a multi-aircraft mission called TRACE-B in Brazil in 1998 across a gradient of key ecosystems to establish the role of the Amazon basin in global atmospheric chemistry change.
- Provide early and continuing detection of stratospheric changes and improve the understanding of such changes by the use of ground-based measurements



The Montreal Protocol on Ozone-Depleting Substances is proving effective, as demonstrated by the change from increasing to decreasing concentrations of this species of the industrially produced chemical trichloroethane. These measurements of concentrations of ozone-depleting substances were taken at five stations in different parts of the globe.



from the Network for Detection of Stratospheric Change (NDSC). Continued monitoring of the trends of existing and new halogen source gases by the ground-based Advanced Global Atmospheric Gases Experiment (AGAGE) network.

- Improve the characterization of global ozone distribution (stratosphere and troposphere) and of long-term changes in this distribution by the use of satellite data sets from TOMS, SAGE, UARS, EOS-MLS, and EOS-TES.
- Improve the process models which parameterize the chemical and photochemical effects on ozone and the global 2D and 3D atmospheric chemical models which are the backbone of the assessment modeling effort for the stratosphere.
- Improve the understanding of the role played by aerosol and cloud particles in controlling the trace constituent distribution of the stratosphere and troposphere through field measurement data input into 3D models.

Objective 1.5 *Understand Earth processes which can lead to natural disasters, develop risk assessment capability for vulnerable regions, and coordinate with U.S. disaster managers and international space agencies.*

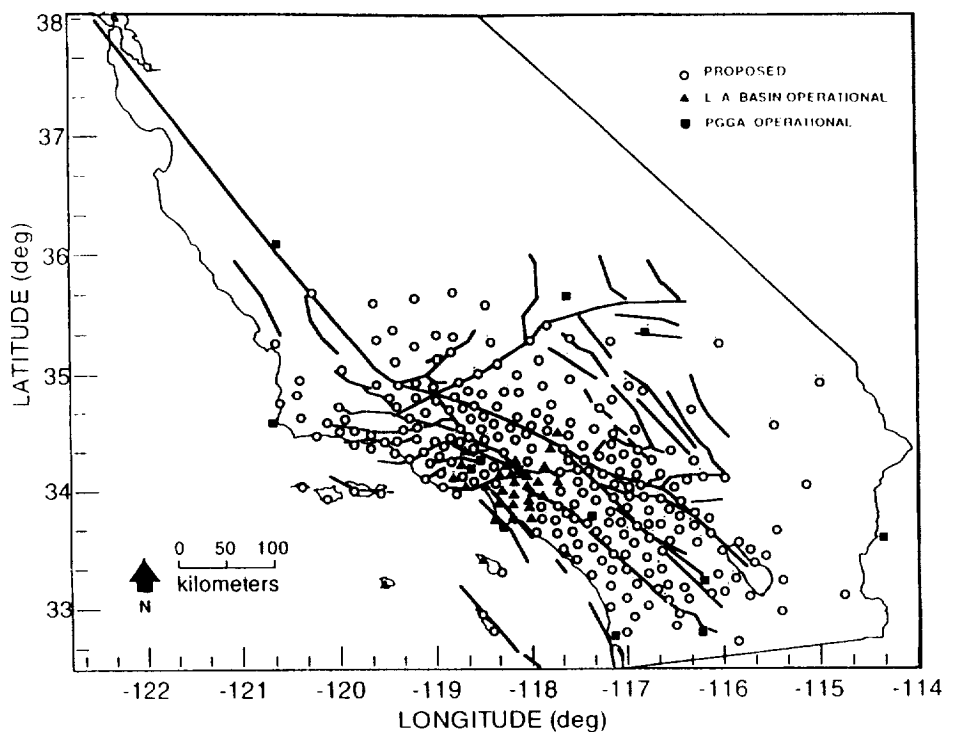
Strategies

- Continue to improve our ability to understand local tectonics and to relate these to seismic hazard vulnerability through advanced space

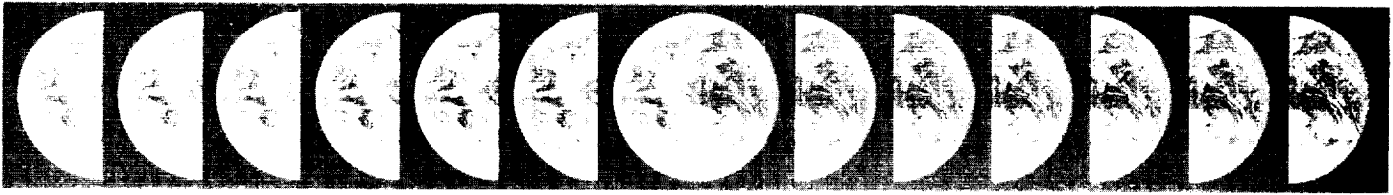
geodetic techniques such as the dense Global Positioning System (GPS) arrays and synthetic aperture radar (SAR) interferometry, focusing on the Los Angeles Basin for GPS array demonstration.

- Develop understanding of the regional disastrous consequences of shorter term climate events such as flooding, monsoon occurrence, storm frequency and severity, and drought.
- Improve the ability to forecast and assess risks of local and regional flooding using watershed models incorporating satellite-derived parameters, such as

Southern California Integrated GPS Network



Location map of 250-station dense array of GPS receivers across the Los Angeles Basin to extend the measurement of seismically related strain. This 7-year experiment will provide the first data set to characterize the relationship between timing of surface deformation and seismic events. The array will also provide leveling information for city infrastructural support and could be used for monitoring microclimate in the metropolitan area.



topography, land cover, recent regional and temporal rainfall history, soil moisture; snow cover (and water equivalent) and snow melt forecasting, and satellite land cover time series in regional drainages.

- Characterize global sea level change through a combination of satellite altimetry, regional tide gauge/geodetic networks, time varying gravity, and global sea surface temperature time series observations. Sea level rise would be manifested in the increased occurrence of coastal flooding. The consequences in terms of coastal habitability and long-term infrastructural planning are profound.
- Develop approach to risk mitigation of the near-shore coastal environment where geologic, ecologic, oceanographic, and meteorological factors can lead to extreme storm surges, regional subsidence, flooding, erosion, and regional bathymetric changes. Characterize the utility of ocean color sensors in tracking habitat of plankton-borne coastal disease vectors.
- Develop robust, transferable technology for remote sensing characterization of wildfire location and intensity, real-time communication for tactical fire fighting decisions, and modeling of wildfire development using local weather conditions and topography. Regional monitoring of NDVI, soil moisture, meteorology could develop short-term vulnerability.
- Develop airborne and satellite capabilities to detect changes in thermal anomalies and the ratio of different volcanic gases and centimeter-scale deformation of a volcano through radar interferometry and GPS techniques to monitor precursor activity at a volcano. Develop digital elevation models to predict the most likely paths of lava flows, lahars, and pyroclastic flows, thereby enabling advance training on hazard mitigation to be directed toward populations at greatest risk. Enhance remote sensing detection of eruption clouds in near real-time for enhanced warning.
- Examine the concept of a network of low-cost,

student-run satellite ground receiver stations which would serve primarily as research and education tools but during disastrous events would be capable of providing real-time services to local and regional disaster officials. Conversion or "recruitment" of existing facilities (such as high data rate X-band receivers currently used for other research purposes) to this end will be included in the study.

- Enhance/establish relationship with disaster management practitioners.
- Coordinate with international space agencies' research, observation, and flight project development programs in natural disaster reduction under bilateral and multilateral conventions.

GOAL 2: Disseminate information about the Earth system

Objective 2.1 *Implement successive releases of EOSDIS in phase with spacecraft launch schedule.*

Strategies

- Continue development of Pathfinder data sets for distribution on EOSDIS Version 0.
- Advance Internet capability/usability of EOSDIS.
- Release EOSDIS Version 1 by January 1997 to support TRMM launch.
- Release EOSDIS Version 2 by October 1997 to support launch of EOS-AM1, Landsat-7, ACRIM, SAGE, and ADEOS.
- Release EOSDIS Version 3 by January 2000 to support launch of RADAR ALT, LASER-ALT, PM-1, and CERES.
- Release EOSDIS Version 4 by November 2001 to support launch of CHEM-1 and SOLTICE.



Objective 2.2 *Foster the development of an informed and environmentally aware public.*

Strategies

- Support student enrichment and research opportunities to train the next generation of Earth system scientists.



GLOBE Students from Gunston School in Centerville, MD measure the moisture of the soil at their school. The students will report their findings via the Internet, and the data will be used by other student and scientists conducting research. (Photo by Steve Delaney)

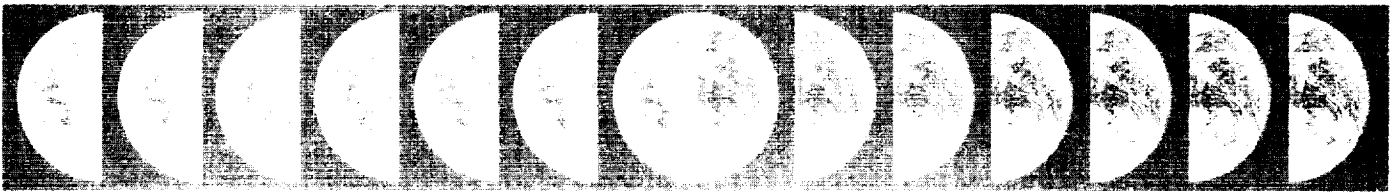
- Emphasize nationwide pre-service and in-service teacher enhancement programs that enable educators to incorporate Earth System Science concepts into their classrooms.
- Support the development of systemic change initiatives that incorporate Earth System Science into the State and local education systems.
- Develop greater support by scientists for broad science communication and education efforts.
- Make information and assessments accessible to the broad continuum of MTPE information customers, including the general public, media, publishers, and industry.

GOAL 3: Enable the productive use of MTPE science and technology in the public and private sectors

Objective 3.1 *Extend the use of NASA's data, models, and research beyond the traditional science community to be applied to the needs of the State, local, and commercial sectors.*

Strategies

- Define the current nonresearch uses of remotely sensed data and the specific data requirements for State, local, and commercial users of the data.
- Establish demonstration and validation pilot projects which apply NASA's data, models, and research in the practicalities of regional or local situations.
- Participate in public and private sector forums to develop an understanding of information needs and establish advantageous partnerships.
- Disseminate the results of demonstration pilot projects and partnerships through a wide variety of venues and outreach activities.
- Implement World Wide Web technology and procedures to enable access to EOSDIS-archived data sets and products via the Internet.



Objective 3.2 *Support the development of a robust commercial remote sensing industry.*

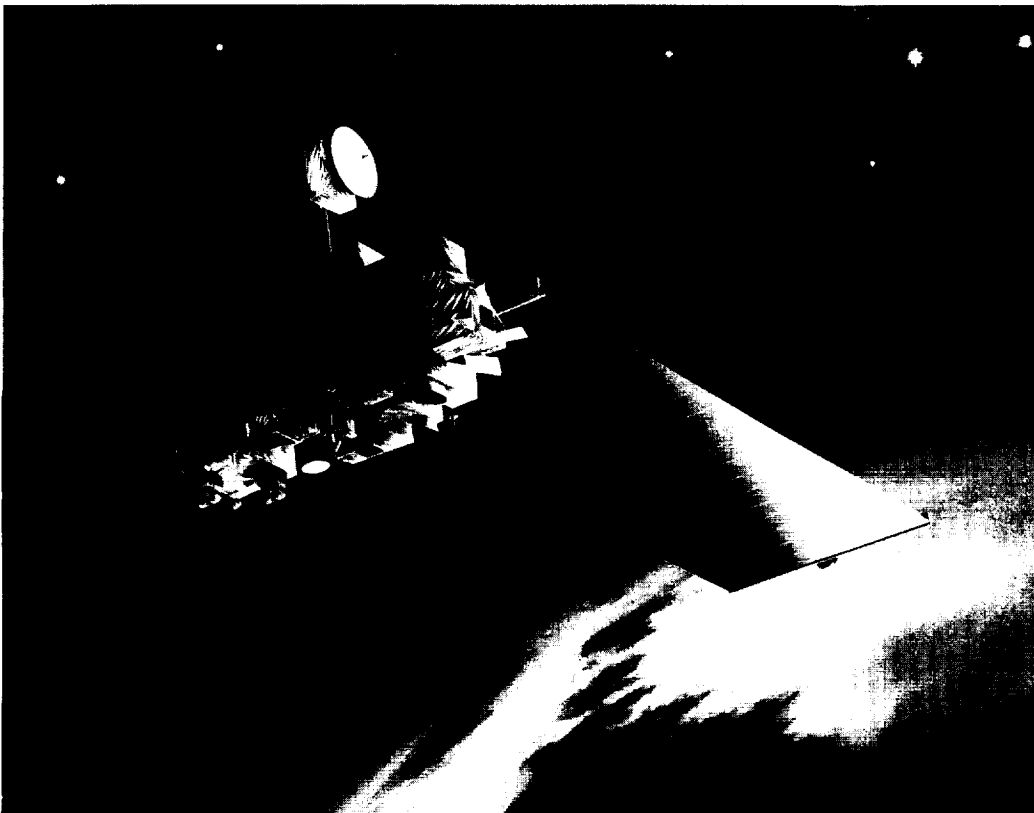
Strategies

- Extend the utilization of NASA's EOSDIS by establishing partnerships with the commercial sector for the dissemination and utilization of the data.
- Establish partnerships with commercial firms to offset risk and cost associated with development of new data products.

Objective 3.3 *Make major scientific contributions to national and international environmental assessments.*

Strategies

- Provide ozone measurements, modeling, and analyses in support of the Intergovernmental Panel on Climate Change's periodic reports.
- Provide analyses of environmental effects of aircraft emissions in a joint program with the Aeronautics Enterprise.
- Provide analyses of land cover change in key regions to measure rates of deforestation, atmospheric impacts of biomass burning, and parameters for contribution to agricultural and other land use assessments.



The EOS-AM1 spacecraft (named to indicate its morning equatorial crossing time), will be launched in mid-1998. Its instrument complement is designed to obtain data on key parameters of global climate change: the physical and radiative properties of clouds; air-land and air-sea exchanges of energy, carbon, and water; measurements of important trace gases, and volcanology.

Section V

Doing Business in New Ways

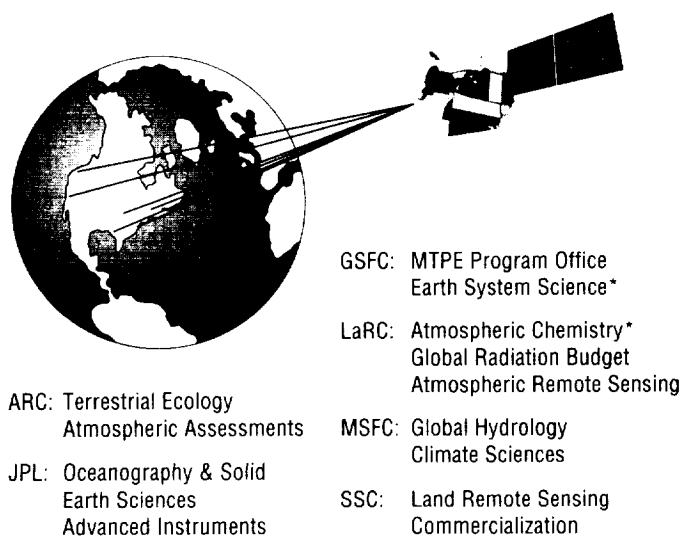
In order to better carry out the research priorities identified in Section III and the objectives and strategies detailed in Section IV, MTPE is implementing the following management approaches.

Program Management

NASA is responding to a Government-wide imperative to do more with less. The NASA Strategic Plan describes the Agency's approach to meeting this challenge. This plan is one tool in a broader, integrated set of strategic management initiatives launched by the Agency. Others include the identification of crosscutting processes and the establishment of metrics to measure performance. MTPE's performance will be measured in terms of progress on the objectives and strategies detailed in Section IV.

Within the MTPE Enterprise, implementation of Federal and Agency mandates encompass the technology initiatives described in Section IV and a realignment of program management responsibilities. Central to this effort is the strengthening of the program management and integration responsibilities of the MTPE Program Office at the Goddard Space Flight Center (GSFC). The Office of Mission to Planet Earth at NASA Headquarters will retain its policy, planning, and requirements development roles, along with management of the science program, while the Program Office at GSFC will be responsible for the day-to-day management of the MTPE spacecraft and information system programs in the implementation phase. Science foci and associated projects are aligned with the expertise of participating Field Installations as shown in the graphic on this page. Implementation of full-cost accounting within the current NASA structure, wherein the costs of civil service personnel, travel, etc., are included in project costs and proposals, will happen in the coming years.

NASA Field Installation Roles in MTPE



* NASA-designated primary center missions

In addition to these internal structural changes, MTPE is employing a number of new business practices as it attempts to identify more effective public/private sector interactions. Government-industry integrated product development teams are a major element of the New Millennium program. In addition, "best value science," optimized "mission-level proposals," reduced Government oversight, and "full-cost" accounting are all elements of the new Earth System Science Pathfinder program.

Science Implementation

As with program management, NASA is taking steps on an Agency-wide basis to maintain the strength of its scientific endeavors. Many of the principles of this effort are contained in "Science in Air and Space: NASA's



Science Policy Guide.” MTPE is moving to a model of conducting science at Field Installations with more cooperative agreements and fewer support contractors. A greater emphasis is being placed on the Field Installation scientists’ roles in outreach to the external science and education communities.

The NASA Zero Base Review recommended the creation of science institutes when the scientific research effort at a NASA Center was not directly connected to a Science Enterprise leadership role. The institutes would tie the in-house science capability to area universities and industry. These institutes would be privatized arrangements in which the current civil service researchers are integrated with institute researchers and Government-owned assets are managed by the university or a consortium. The institute would receive the majority of its funds through the competitive peer review process although it could receive direct funding when performing a unique role necessary to accomplish the Enterprise Strategic Plan.

Commercial Strategy

MTPE is developing a commercial strategy with the goal “to stimulate and leverage commercial capabilities in remote sensing and information systems in order to cost-effectively meet MTPE science objectives and enhance the relevance of scientific discovery.” Currently, a fully capitalized, self-sustaining market does not exist in any area of Earth observations from space. Advances in technology and expansion in applications of remote sensing data have the potential to change this in the coming decade. To foster and capitalize on this potential, MTPE will:

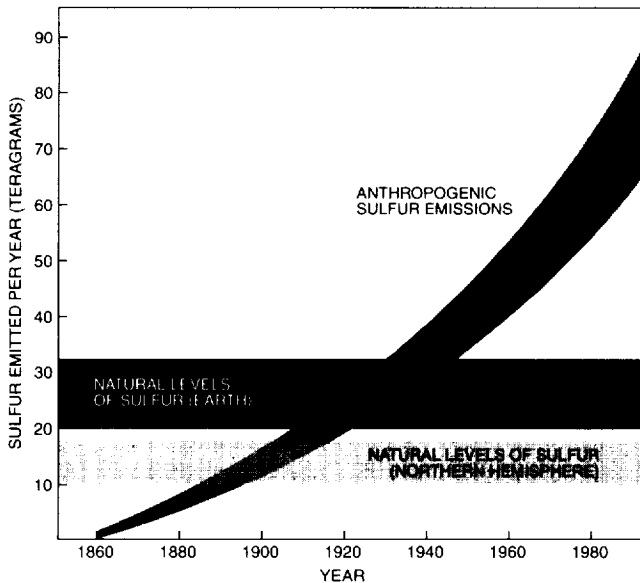
- Develop clear principles and consistent policies
- Identify and encourage value-added applications of MTPE data

- Exploit industry capabilities in data and information management systems
- Seek technology development and applications partnerships
- Seek cost-effective science data purchase opportunities, including privatization
- Create opportunities by informing and consulting industry as part of MTPE program planning

A separate commercial strategy document will define the policies and actions to be taken in coordination with industry over the coming few months and years (see Appendix 2: References).

NASA/NOAA Alignment

The opportunity to save money and enhance research capabilities was the impetus for a new effort to seek a closer alignment of NASA and NOAA in the areas of data systems, technology, and program synergy. In the data systems area, the two agencies are examining ways to integrate NOAA information technology requirements with EOSDIS and consolidate the NASA and NOAA information services structures. Common locations for ground stations and common operations out of the GSFC EOS Operations Center are also being considered. In the spacecraft and instrument technology area, the agencies find that NASA’s New Millennium program can also benefit NOAA’s operational weather satellite programs. Potential for substantial cost savings exists through increased integration of NASA’s EOS-PM satellites and the National Polar-orbiting Operational Environmental Satellite System, a joint NOAA/DoD/NASA program. Greater collaboration in modeling and data assimilation, algorithm development, and research data processing are among the benefits of synergy brought about by collocation of research personnel. As a cost saving and consolidation measure on its part, NOAA has proposed moving its satellite operations and related research activities to a



Sulfur dioxide (SO_2) emissions from human activities, primarily fossil fuel combustion and metal smelting, have increased substantially over the industrial period. Such emissions now substantially exceed, on a global basis, natural emissions (mainly from marine phytoplankton) of sulfur-containing gases into the atmosphere.

site on the NASA GSFC campus. Such a move would increase the effectiveness of joint activities.

Integrated Global Observing Strategy

Both our scientific understanding of the Earth system and the practical applications of this understanding worldwide are increasing at a rapid pace. At the same time, however, the availability of funding within national governments for the deployment of observing systems is not. Increased international collaboration is required, and national governments and international organizations are beginning to consider the benefits of an Integrated Global Observing Strategy (IGOS). NASA and its partner agencies are formulating the IGOS concept and coordinating it internationally via the interagency Task Force on Observations and Data

Management of the Committee on Environment and Natural Resources, a part of the President's National Science and Technology Council.

An IGOS would accomplish three important tasks. The first is coordinating the recommendations of international user groups with different yet sometimes overlapping data requirements, to promote the implementation of multipurpose observing and data systems. Because environmental monitoring often spans national boundaries, the second task will be to ensure coordinated national commitments to the long-term implementation of the various components of a coherent global system. Lastly, a similar coordination effort will be required of operating agencies, including both space-based and *in situ* observing systems and their associated data systems, in order to minimize duplication and enhance the complementary nature of each component. While multidecadal in its implementation, the goal is to gain national and international acceptance of the IGOS concept and framework over the next year. A fuller expression of progress to date in this effort is found in "Concept for an Integrated Global Observing Strategy," a report of the Task Force to the Committee on Environment and Natural Resources.

Linkages to Other Enterprises

The goals, objectives, and strategies of MTPE could not be accomplished without support from the other NASA Strategic Enterprises.

The *Space Science Enterprise* is integrally linked to MTPE, through the joint development of spacecraft and instrument technologies which support each program (through the jointly funded New Millennium program), through the development of science institutes capable of providing world-class support to sustain NASA's leadership role in space and Earth sciences, and through coordinated



development of programmatic objectives. The Space Science Enterprise also enriches MTPE through studies of the Sun, the near-Earth space environment, the Earth's middle and upper atmosphere, and other planets. The studies of Mars and Venus, in particular, provide important context for understanding why the Earth is capable of sustaining life and how some of the processes involved in global change behave in other planetary settings.

The **Space Technology Enterprise** develops new Earth-orbiting spacecraft and remote sensing instrument technologies which we will incorporate in EOS. The Lewis and Clark spacecraft are of particular importance in this arena. In addition, the Space Technology Enterprise assists MTPE with transfer of technologies to the private sector.



NASA's DC-8 is a unique national asset. This highly modified aircraft is really a flying laboratory, capable of carrying a large number of instruments and scientists anywhere in the world. The DC-8 is used for investigations in tropospheric chemistry, terrestrial ecology, geology, and ice cover. One such investigation is the BOREAS campaign, which uses a unique airborne radar system, AIRSAR, to study the boreal forests of Canada.

The **Human Exploration and Development of Space (HEDS) Enterprise** provides the services of the Space Shuttle for our Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR), the proposed Shuttle Radar Topography Mission, the Shuttle Laser Altimeter, and other missions. HEDS will also provide accommodations on the International Space Station for SAGE III, which is one of the instruments in the EOS program. There is also an interaction between MTPE and HEDS science and technology goals and objectives with respect to global medicine and disaster response.

We are partnering with the **Aeronautics Enterprise** in the study of the impact of aircraft emissions on the atmosphere. MTPE and the Office of Aeronautics, through its Atmospheric Effects of Aviation Program (AEAP), jointly support the instrument development, field measurements, and modeling efforts needed to address this issue in the context of other atmospheric issues. AEAP studies aviation-specific issues, such as aircraft engine emissions and aircraft wake-near field interactions. Aeronautics also supports the development of new aircraft and instruments through its ERAST program.

Section V

Pressing Toward the Mark: Linking Actions to Desired Outcomes

Goal 1: Expand Scientific Knowledge*

OBJECTIVE	PRINCIPAL ACTIVITIES	OUTPUTS	OUTCOMES	CUSTOMERS & BENEFICIARIES
UNDERSTAND LAND- COVER CHANGE AND GLOBAL PRODUCTIVITY	Landsat 7/ETM+ Lewis HSI MODIS ASTER MISR Field campaigns and regional studies Modeling	Global & Regional Land Cover Maps Fluvial transport Nutrient budgets Rates of land-cover/use change Consequences of land cover change	More efficient forestry practices Better pollution management Better ecosystem management More efficient urban planning Better world crop estimates High-precision agriculture	Ecosystem science community Forestry and Farming Stewards of coastal and other fragile ecosystems City managers & transportation planners Fishing Industry Recreation Industry U.S. & foreign agricultural agencies
UNDERSTAND SEASONAL- TO-INTERANNUAL CLIMATE VARIABILITY	TRMM TOPEX/Poseidon Modeling & Analysis AIRS AMSU CERES MODIS MHS Passive Microwave SAGE SeaWiFS MODIS NSCAT (ADEOS) Field Campaigns, modeling, & data assimilation SSM/I INSAT SSM/I SAR	Coupled model simulations of the upper ocean/atmosphere/ land climate system New lidar & radar technologies Maps of ocean biomass and productivity and regional precipitation Prediction of seasonal and inter- annual climate events (El Niño, etc.) Influence of volcanoes on climate Global water vapor maps Analysis of weather and flood variability Risk Assessment studies Monsoon onset analyses Variability in sea-ice cover	Improved weather forecasts and climate prediction Planting strategies for farming More efficient fisheries Improved management of heating and cooling energy resources Better flood and drought mitigation strategies Better crop estimates Economic savings from more accurate planning Better forecast of world rice production Improved sea-ice forecasts Improved weather forecasts	Climate science community Farming and Forestry Commercial fishing industry Disaster relief agencies Water resources management U.S. & foreign agricultural agencies Insurance industry Energy Industries Defense agencies Travel and tourism industry International food supplies High latitude fisheries, shipping, & oil drilling
UNDERSTAND LONG-TERM CLIMATE VARIABILITY	HALOE MLS AIRS/AMSU/MHS SAGE III GOALS Process Studies & Modeling Climate Change Assessments SeaWiFS MODIS POES/NPOES MSU GLAS ALT SAR SSM/I MODIS AVHRR CERES ACRIM SOLSTICE	Predictive estimates of future variation of the climate system Changes in marine ecosystem structure Estimates of sea level change Estimates of average surface temperature change Long-term impacts of El Ninos, tropical cyclones, etc. Global moisture availability variation Long-term stratospheric temperature trends Changes in volume of terrestrial ice and their causes Long-term trends in sea-ice cover Long term measurements of total solar & UV irradiance	Risk management strategies for coastal zones Effects on fish stocks Informed industrial and govern- mental decisions on mitiga- tion strategies Estimates of effects on sustain- able development strategies for food, water, energy, etc. Explain natural global temperature variation Estimate future food production Estimate risk to future populations Understanding sea-level change and improved predictions Improved climate models	Climate science community Federal, State and local govern- ments and regional authori- ties Fishery industries Insurance industry Energy industries Farming & forestry Water resources management Global community interactions sustainable development planners Coastal communities Coastal wetlands Coastal pollution Policymakers

* Sensors may contribute to multiple outputs, outcomes, and customers. There is not a one-to-one correspondence across columns.



Goal 1: Expand Scientific Knowledge* (cont'd)

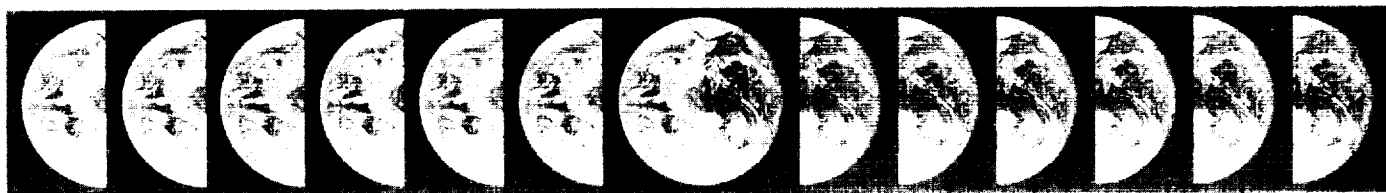
OBJECTIVE	PRINCIPAL ACTIVITIES	OUTPUTS	OUTCOMES	CUSTOMERS & BENEFICIARIES
UNDERSTAND DISTRIBUTION OF ATMOSPHERIC OZONE	HALOE MLS TES MLS HIRDLS ODUS TOMS, SAGE III, ADEOS STRAT, POLARIS TOTE/VOTE, PEM-Tropics Modeling & Analysis	Continued monitoring of stratospheric ozone Initial monitoring of tropospheric ozone Assessment of effects of aircraft emissions UV light levels Delineation of the roles of chemical & transport processes on the global distribution of ozone in the stratosphere and troposphere Characterization of natural and anthropogenic forcings on ozone abundance and distribution and the attendant effects on climate & UV radiation on the ground.	Evaluation of effectiveness of international agreements on the photochemical recovery of stratospheric ozone Identification of distribution and sources of tropospheric ozone Effects on marine life Assessment of effects of aircraft emissions	Atmospheric science community National and international environmental and health agencies U.S. manufacturing U.S. aircraft industry Recreation industries International regulatory authorities NOAA operational ozone monitors
IMPROVE DISASTER CHARACTERIZATION & RISK REDUCTION	GPS array technology Remotely sensed SAR interferometry time series Airborne measurements Process studies & modeling EOS Direct Broadcast for world warning MODIS SeaWiFS ASTER LANDSAT 7/ETM+ SRTM TOMS TOPEX/Poseidon T-P Follow-on/EOS-ALT-R GLAS SAR Lewis & Clark	Characterize of pre-, syn- and post-seismic regional surface deformation & seismic activity Multi-faceted approach toward forecasting local and regional flooding, droughts & landslide potential More frequent and accurate typhoon, hurricane and flood observations Location of toxic blooms	Transfer to technology for location and characterization of hazards to Federal and some state agencies Establish an international Global Sea Level Change Characterization program Saving of lives and property due to evacuation and property protection Disease outbreak prediction and prevention	Solid Earth science community Federal, State, and local governments and regional authorities U.S. industry World Meteorological Organ. World Health Organization National Meteorological Agencies PTT's CNN Regional warning centers Recreation industries Health agencies

* Sensors may contribute to multiple outputs, outcomes, and customers. There is not a one-to-one correspondence across columns.



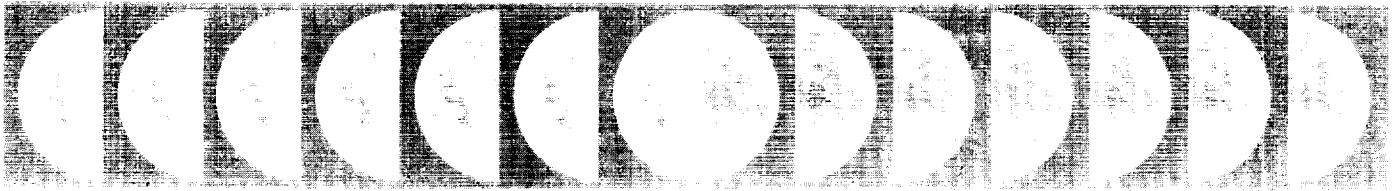
Goal 2: Disseminate Information

OBJECTIVE	PRINCIPAL ACTIVITIES	OUTPUTS	OUTCOMES	CUSTOMERS & BENEFICIARIES
IMPLEMENT SUCCESSIVE RELEASES OF EOSDIS IN PHASE WITH SPACECRAFT LAUNCH SCHEDULE	Continue development of Pathfinder data sets for distribution on EOSDOS v0 Expand accessibility over the Internet	Analysis of global variation of temp., precipitation and ocean color, ocean winds, atmos moisture, clouds aerosols weather phenomena	Establish a background time and space variability spectrum to allow measurement of global change	Worldwide Earth system science community Value-added remote sensing processing industry Assessors of population growth impacts Sustainable development managers Food and textile industries
	EOSDIS Releases: v1 TRMM v2 AM1, L-7, ACRIM, SAGE, ADEOS v3 PM-1, RADAR-ALT, LASER-ALT, CERES v4 CHEM-1, SOLTICE	221 Standard Data Products Archival and Distribution Services	Improved analyses of global Earth system variables, leading to improved understanding and modeling of Earth system processes.	Worldwide Earth system science community Value-added remote sensing processing industry
FOSTER THE DEVELOPMENT OF AN INFORMED AND ENVIRONMENTALLY-AWARE PUBLIC	Student enrichment and research opportunities Nationwide in-service and pre-service teacher enhancement programs Systemic change initiatives Scientist involvement in public communication Expand accessibility of MTPE information to broad community, including the general public	Research fellowships Young investigator programs Public workshops/meetings Media awareness/coverage	Improved scientific and technical literacy in the U.S. general public U.S. leadership in science in the next generation More adequate supply of skilled and informed workers for U.S. industry	College & graduate students In-service and pre-service teachers and their students Libraries, museums, and planetariums Media organizations Publishers of teaching materials General public



Goal 3: Enable the Productive Use of MTPE Science & Technology

OBJECTIVE	PRINCIPAL ACTIVITIES	OUTPUTS	OUTCOMES	CUSTOMERS & BENEFICIARIES
APPLICATIONS PROGRAMS	Demonstration of NASA data utility in GIS context for non-research applications	Integrated user needs assessment MTPE data products applications assessments	Increased relevance of science results to more immediate public needs	State and local planners Natural resource managers
		Validation & demonstration pilot projects	Increased use of NASA data products	Land use decision makers at local and regional levels
	Extension of EOSIDS to regional and discipline specific data access customers	Pilot PARC's	Greater return on taxpayer investment	Other Federal agencies, e.g., USDA, Forest Service etc.
COMMERCIAL STRATEGY	Commercial outreach	Information dissemination External Review Panel Enhanced program acquisition processes	Greater commercial participation in AO's and grants	Industry, universities, and other NGO's
	Stimulate commercial use of govt. data	Applications prototypes Improved data access by users	Expanded Value-added market Enhanced technology transfer	Industry, universities, and other NGO's Educators State and local governments
	Purchase commercial data	Commercial Data Use Agreements Policies and procedures for using commercial data	Lower cost science data	NASA and NASA-sponsored engineers and scientists
	Facilitate access to govt. assets	Industry partnerships to use NASA labs, calibration facilities, and space based assets	Improved NASA facility use Provide "Piggyback" flight opportunities Joint product developments Enhanced technology transfer	Industry, universities, and other NGO developers NASA Centers
	NASA use of commercial assets	NASA partnerships to use commercial satellites, aircraft, in situ data, and ground support systems	NASA cost savings Supports commercial development	NASA programs and Centers



Goal 3: Enable the Productive Use of MTPE Science & Technology (cont'd)

OBJECTIVE	PRINCIPAL ACTIVITIES	OUTPUTS	OUTCOMES	CUSTOMER & BENEFICIARIES
TECHNOLOGY TRANSFER ACTIVITIES	Implement NASA's Commercial Technology "Agenda for Change" within MTPE participate in NASA's Commercial Technology Management Team	Enhanced MTPE acquisition policies and procedures	Greater commercial participation in the MTPE program Greater public sector, especially commercial industry, benefit from participation in MTPE programs	Industry, universities, and other NGOs
	Integrate OMTPE into NASA's Environmental Technology Network	World Wide Web information exchange	More informed public sector and commercial industry	Industry, universities, and other NGOs
	Prototype Public Access Resource Center (PARC)	Extended use of MTPE science data through a prototype demonstration	Cost-effective, scientifically based data for the agribusiness world	Public and private sector agribusinesses and related users
ENVIRONMENTAL ASSESSMENTS	Assessments of changes in concentration/distribution of stratospheric ozone Atmospheric effects of aircraft emissions Land cover change in key regions	Reports and briefings to international organizations, Congressional committees, Executive offices, and industry	Verification of effectiveness of international treaties Parameters for aircraft design Informed policy decisions by national governments on land management	OSTP International research programs, e.g., WMO, IPCC, IGBP Aircraft manufacturers National governments

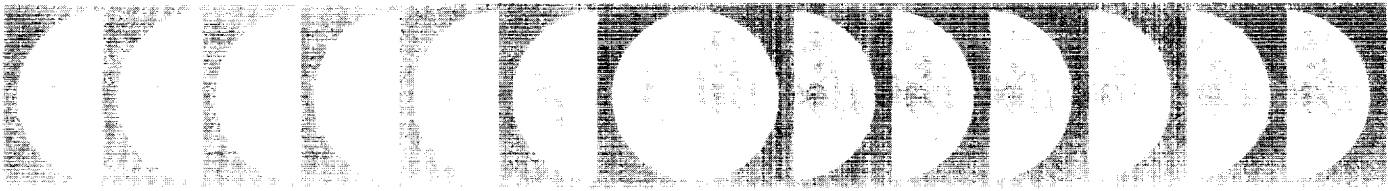
Appendix

Appendix 1: Acronyms

ACRIM	Active Cavity Radiometer Irradiance Monitor	EOSDIS	EOS Data and Information System
ADEOS	Advanced Earth Orbiting Satellite (Japan)	EOSP	Earth Observing Scanning Polarimeter
AEAP	Atmospheric Effects of Aviation Program	ERAST	Experimental Research Aircraft Sensor Technology
AGAGE	Advanced Global Atmospheric Gases Experiment	ESSAAC	Earth System Science and Applications Advisory Committee
AIRS	Atmospheric Infrared Sounder	ESSP	Earth System Science Pathfinder
ALT	Altimeter	ETM+	Enhanced Thematic Mapper-Plus
AMR	Altimetry Microwave Radiometer	FOO	Flight of Opportunity
AMSU	Advanced Microwave Sounding Unit	GAO	General Accounting Office
ARC	Ames Research Center (Moffet Field, CA)	GEWEX	Global Energy and Water Cycle Experiment
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer	GLAS	Geoscience Laser Altimeter System
BSD	Board on Sustainable Development	GOALS	Global Ocean-Atmosphere-Land System (WCRP program)
CERES	Clouds and the Earth's Radiant Energy System	GSFC	Goddard Space Flight Center (Greenbelt, MD)
CGCR	Committee on Global Change Research	HALOE	Halogen Occultation Experiment
CIESIN	Consortium for International Earth Science Information Network	HEDS	Human Exploration and Development of Space
CLIVAR	Climate Variability (WCRP program)	HIRDLS	High Resolution Dynamics Limb Sounder
DAAC	Distributed Active Archive Center	IGBP	International Geosphere-Biosphere Programme
DOD	Department of Defense	IGOS	Integrated Global Observing Strategy
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite	IPCC	Intergovernmental Panel on Climate Change
ECS	EOSDIS Core System	JPL	Jet Propulsion Laboratory (Pasadena, CA)
EDOS	EOS Data and Operations System	LaRC	Langley Research Center (Hampton, VA)
ELV	Expendable Launch Vehicle	LeRC	Lewis Research Center (Cleveland, OH)
EOCAP	Earth Observation Commercial Applications Program	LATI	Landsat Advanced Technology Instrument
EOS	Earth Observing System	LIS	Lightening Imaging Sensor
EOS-AM1	EOS morning equatorial crossing (descending) satellite	MELV	Medium Expendable Launch Vehicle
EOS-CHEM1	EOS Chemistry satellite	MHS	Microwave Humidity Sounder
EOS-PM1	EOS afternoon equatorial crossing (ascending) satellite	MIMR	Multi-frequency Imaging Microwave Radiometer



MISR	Multi-angle Imaging SpectroRadiometer	SAGE III	Stratospheric Aerosol and Gas Experiment III
MLELV	Medium-Lite Expendable Launch Vehicle	SAR	Synthetic Aperture Radar
MLS	Microwave Limb Sounder	SeaWiFS	Sea-Viewing Wide Field Sensor
MODIS	Moderate-Resolution Imaging Spectroradiometer	SIR-C/X-SAR	Spaceborne Imaging Radar-C/X-band SAR
MOPITT	Measurements of Pollution in the Troposphere	SOLSTICE	Solar Stellar Irradiance Comparison Experiment
MSFC	Marshall Space Flight Center (Huntsville, AL)	SONEX	Subsonic Ozone and Nitrogen Experiment
MTPE	Mission to Planet Earth	SSALT	Solid-State Altimeter
ODUS	Ozone Dynamics Ultraviolet Spectrometer	SSC	Stennis Space Center (Slidell, MS)
NAS	National Academy of Sciences	SSM/I	Special Sensor Microwave/Imager
NASA	National Aeronautics and Space Administration	STRAT	Stratospheric Tracers of Atmospheric Transport
NDSC	Network for Detection of Stratospheric Change	TDRSS	Tracking and Data Relay Satellite System
NGO	Non-Governmental Organization	TES	Tropospheric Emission Spectrometer
NMP	New Millennium program	TMI	TRMM Microwave Imager
NOAA	National Oceanic and Atmospheric Administration	TOMS	Total Ozone Mapping Spectrometer
NPOESS	National Polar-orbiting Operational Environmental Satellite System	TOPEX/Poseidon	Ocean Topographic Experiment (w/France)
NRC	National Research Council	TRACE-B	Transport and Chemistry near the Equator-Atlantic (2nd)
NSCAT	NASA Scatterometer	TRMM	Tropical Rainfall Measuring Mission (w/Japan)
OMS	Observation from the Middle Stratosphere	UARS	Upper Atmosphere Research Satellite
OSTP	Office of Science and Technology Policy	USDA	United States Department of Agriculture
OTD	Optical Transient Detector	USGCRP	United States Global Change Research Program
PARC	Public Access Resource Center	UV	Ultraviolet
PEM	Pacific Exploratory Mission	VIRS	Visible InfraRed Scanner
POLARIS	Photochemistry of Ozone Loss in the Arctic Region in Summer	VOTE/TOTE	Vortex Ozone Transport Experiment/ Tropical Ozone Transport Experiment
PR	Precipitation Radar	WCRP	World Climate Research Program
RPV	Remotely Piloted Vehicle		



Appendix 2: References

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- Atmospheric Ozone Research
- Land-Cover Change and Global Productivity
- Long-Term Climate System Variability
- Natural Hazards Research
- Seasonal-to-Interannual Climate Variability

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Contribution of Working Group 1 to the Second Assessment Report of the Intergovernmental Panel on Climate Change, 1996, Editors, J.J. Houghton, et al.

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January 1988, Earth System Science Advisory Committee of the NASA Advisory Council



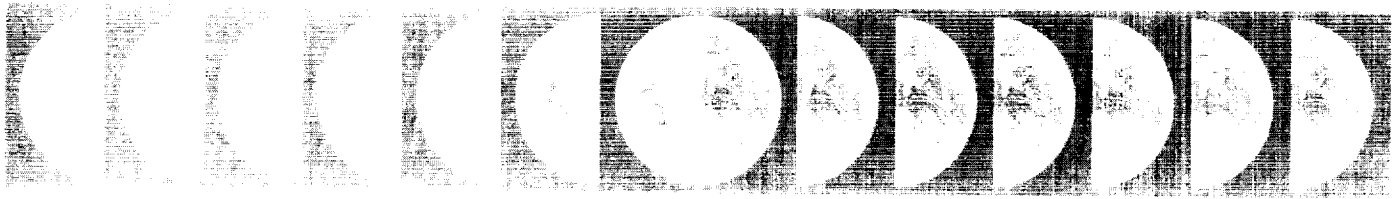
Appendix 3: Mission to Planet Earth Launch Schedule (Through 2002)

March 7, 1996 (for planning purposes only)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1991		Meteor-3			NOAA-D (AVHRR)		SRS-1	SRS-1 TOMS (METEOR-3)	URS		DMSP-11 (SSM/1)	
1992		JERS-1	ATLAS 1 (SSBUV-A-01)					TOPEX/POSEIDON		LAGEOS-2		
1993				ATLAS 6 (SSBUV-A-02)				NOAA-18* (AVHRR)	AOTS		MARS-96	
1994		GMS-5	SSBUV-A-03	SRL-1 GOES-8				DMSP-12 (SSM/1)	LITE SRL-2		ATLAS-3 (SSBUV-A-04)	NOAA-J (AVHRR)
1995			DMSP-13 (SSM/1)	OTO	NOAA-J					NOAA-16		
1996	SSBUV-A-05	TOMS EP-95 SEASTAR		NOAA-K (AVHRR)	Orsted SUNSAT	CLARK	LEWIS	ADEOS (TOMS/NSCAT)		DMSP-14 (SSM/1)		
1997			GOES-K				COAST-2000	TRAM	NOAA (AVHRR)			
1998					DMSP-15 (SSM/1)	EOS-AM1		SAGE METEOR-3M	ENVISAT 1		NOAA-M (AVHRR)	LANDSAT-7
1999	ADEOS-2 (TOMS)	EOS-ATLAS	NOAA-17					DMSP-16 (SSM/1)				ADEOS-2
2000		HIROS 1		GOES-L		METOP 1		METEOR 3M/TOMS RADARSAT-2	NOAA-N (AVHRR)			EOS-PM1
2001												
2002												

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Internet Addresses

DAAC's: Distributed Active Archive Centers

ASF DAAC:

<http://goofy.gi.alaska.edu:12355>

EDC DAAC:

<http://sun1.cr.usgs.gov/landdaac/landdaac.html>

Goddard DAAC:

<http://daac.gsfc.nasa.gov>

JPL DAAC:

<http://seazar.jpl.nasa.gov>

Langley DAAC:

<http://eosdis.larc.nasa.gov>

Marshall DAAC:

<http://wwwdaac.msfc.nasa.gov>

NSIDC DAAC:

<http://eosims.colorado.edu:1733>

ORNL DAAC:

<http://www-eosdis.ornl.gov>

SEDAC DAAC:

<http://www.ciesin.org>

Earth Data & Imagery

AVHRR Land Pathfinder:

<http://xtreme.gsfc.nasa.gov>

JPL TOPEX/POSEIDON Images:

<http://podaac-www.jpl.nasa.gov/topex>

AVISO TOPEX/Poseidon data:

<http://192.134.216.41>

Oceans SST Pathfinder (NOAA/NASA):

<http://sst-www.jpl.nasa.gov>

NASA/JPL Imaging Radar Homepage:

<http://southport.jpl.nasa.gov>

SIR-C/XsSAR images:

<http://www.jpl.nasa.gov/sircxsar.html>

The World-Wide Web Library: Oceanography:

<http://www.mth.uea.ac.uk/ocean/oceanography.html>

MTPE Home Page

<http://www.hq.nasa.gov/office/mtpe/>



National Aeronautics
and Space Administration

March 1996